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WE CAN BUILD JURASSIC WORLD

How science will bring extinct creatures to a theme park near you

Q&A

What happened to acid rain?

Why do dogs like being stroked?

Can we detect dark matter?

Why do we forget dreams?

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THE HIDDEN FORTUNE IN OUR SEWERS

MEDIEVAL DISEASES

CAN YOU STILL CATCH BUBONIC PLAGUE?

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WELCOME

BACK IN 1993, *Jurassic Park* thrilled us with the prospect of resurrecting dinos from ancient scraps of DNA. In the new film, *Jurassic World*, the theme park is finished and full of paying customers. But are we any nearer to bringing back extinct animals… and how would we manage them in a real wildlife park? Brian Clegg gives a guided tour on p33.

Along with dinosaurs, I thought bubonic plague had died out long ago. Shockingly, it's still with us – as are other diseases associated with the Middle Ages. On p58 we find out how people catch them and how to recognise the symptoms.

Clean water is hugely important for stopping disease, but many places are facing severe droughts this summer. California is tackling the problem with desalination plants, and we investigate these and other technologies on p44.

We should be conserving water, but human waste? It might not sound so crazy when you consider that it contains gold! Find out more on p62.

There may also be gold on the Moon. It's one reason why companies want to develop robots to explore the lunar surface, as we report on p88.

Finally, you may have been watching the stunning BBC series on sharks – on p50 we pay tribute to the great white with a feast of fascinating facts.

Graham

Graham Southorn, Editor

PS Don't miss our Summer issue, on sale 25 June 2015

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THIS MONTH WE…

…spent a night underneath Dippy the dinosaur at the Natural History Museum as part of their Dino Snores For Grown-ups event. Read our review at http://bit.ly/1H1csV5

…visited the UK's first digital 3D planetarium at the At-Bristol science centre. We enjoyed a stunning view of the night sky and a visit to Saturn. To read our review, visit http://bit.ly/1GQLo8v

…trialled the Hövding airbag for cyclists. To see if production editor Alice survived this nasty-looking fall, watch the video on our YouTube channel at youtube.com/user/ScienceFocus

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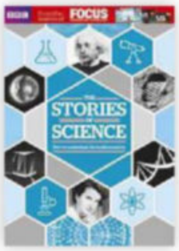

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APPEARING IN THIS ISSUE…

Hayley Birch

Hayley is a science writer and co-author of *The Big Questions In Science*. She investigates new technologies that could help put an end to droughts on p44.

Brian Clegg

Brian is an award-winning writer of popular science books including *Science For Life*. On p33 he looks into the possibility of bringing back dinos to roam in a real *Jurassic Park*.

Zoe Cormier

Scientists have discovered that we're flushing millions of pounds down our toilets every year. On p62, former environmental reporter Zoe does some digging…

Lewis Dartnell

Lewis is the author of *The Knowledge: How To Rebuild Our World From Scratch*. He gives us the benefit of his wisdom on p106 as we look at the challenges faced by Mad Max.

WANT TO SUBSCRIBE? Turn to p30 to save **40%** on the shop price of *BBC Focus*

SUBSCRIBER BONUS On p30, **Dr Paul Coxon** discusses the substances that could revolutionise our batteries and solar panels

COVER: ANDY POTTS DINOSAUR FOSSIL SCULPTURE: LARION POLACSEK

CONTENTS JULY 2015

ON THE COVER

15 DESIGNER BABIES
33 JURASSIC WORLD
50 THE GREAT WHITE
52 ALIEN LIFE
58 BUBONIC PLAGUE
62 SEWER FORTUNES
69 Q&A
84 SUMMER GADGETS
88 RACE TO THE MOON
106 MAD MAX

FEATURES

33 HOW WE'LL BUILD A REAL JURASSIC WORLD
Can we really bring back ancient animals?

44 WHEN THE WELL RUNS DRY
Technology can help with the problem of drought

50 YOU'RE GONNA NEED A BIGGER BOAT
We dive into the science behind the great white

52 WHERE ARE ALL THE HABITABLE PLANETS?
The hunt for alien life

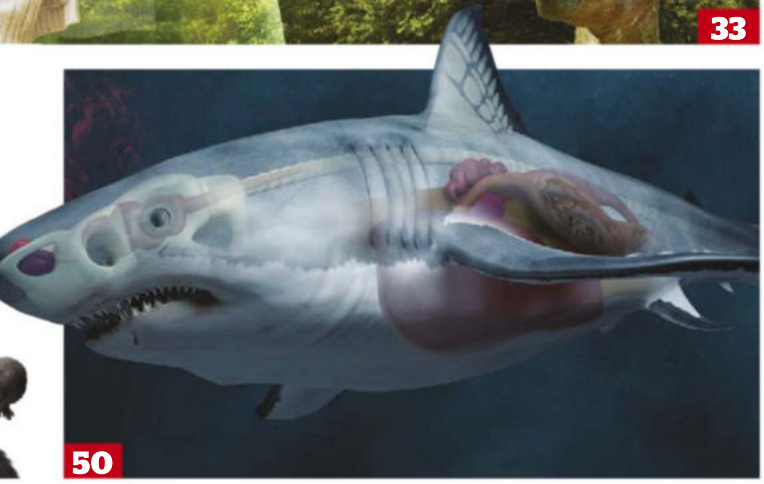
58 CAN YOU CATCH THE PLAGUE?
A host of icky diseases are still lurking out there

62 WASTE NOT, WANT NOT
Harnessing poo's power

88 THE ROBOTIC RACE TO THE MOON
XPRIZE's prime contenders

33

58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44

52

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84

29

88

27

This GENeco Bio-Bus is powered by your waste for a sustainable future
GENeco
62

15

DISCOVERIES

15 DESIGNER EMBRYOS
The first step towards choosing your child's eye colour?

22 BATS' EXTRAORDINARY FLYING SKILLS REVEALED
It's all down to some nifty cells

24 ASTRONOMERS FIND VOLCANIC PLANET
A rocky super-Earth is teeming with smoke and ash

26 OBSERVED: THE PRECISE MOMENT THE BRAIN MAKES A DECISION
Daddy or chips… ?

COLUMNS

18 DAVID SHUKMAN
Air pollution is choking China

23 ROBERT MATTHEWS
Don't use the Argument from Omniscience

27 HELEN CZERSKI
Water your plants regularly or face their wrath

29 STEPHEN BAXTER
Could high-tech robots replace doctors and nurses?

106 HOLLYWOOD SCIENCE
Apocalypse life with *Mad Max*

TECH HUB

79 TESLA POWERWALL
Reliable renewable energy

81 BILL THOMPSON
Nanotechnology will revolutionise our lives

81 FROM THE LAB
Seven-league boots are here! Well, sort of…

83 APPLIANCES OF SCIENCE
We want a dust-sucking bin

84 ULTIMATE TEST
Holiday gadgets galore

TO DO LIST

93 PICK OF THE MONTH
Catching History's Criminals: The Forensics Story

94 WATCH
This month's top TV picks

96 LISTEN/TOUCH
Radio shows, smartphone and tablet apps

97 VISIT
Great talks and days out

98 READ
The latest science books reviewed by the experts

PLUS…

6 MEGAPIXEL
Stunning science images from around the world

11 REPLY
Your letters and emails

69 Q&A
This month: why do we forget our dreams, why do animals like being stroked, are fitness trackers accurate, plus many more

105 MINDGAMES
Give your grey matter a workout with this crossword

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Awe-inspiring images from the world of science

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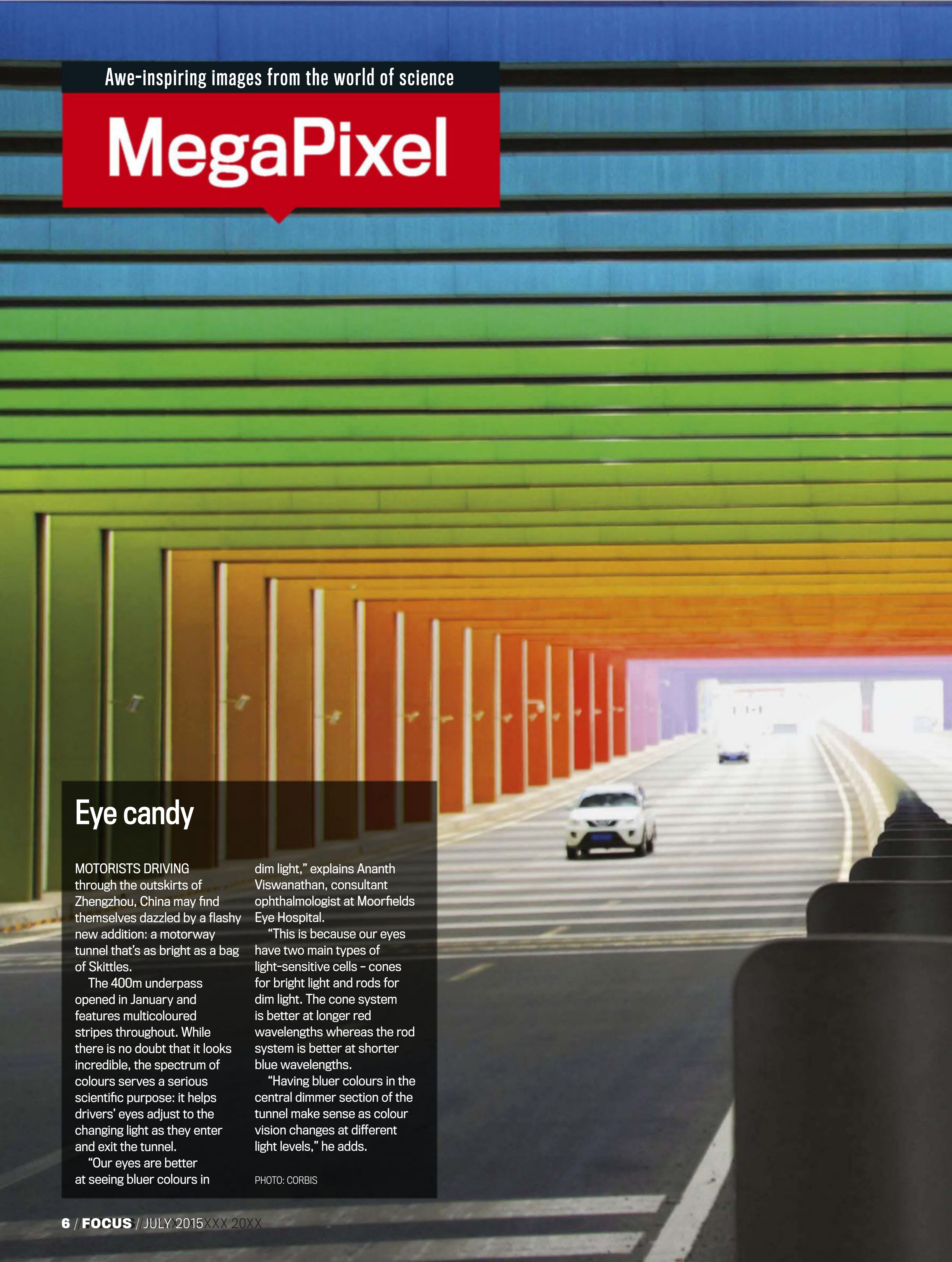


Eye candy

MOTORISTS DRIVING through the outskirts of Zhengzhou, China may find themselves dazzled by a flashy new addition: a motorway tunnel that's as bright as a bag of Skittles.

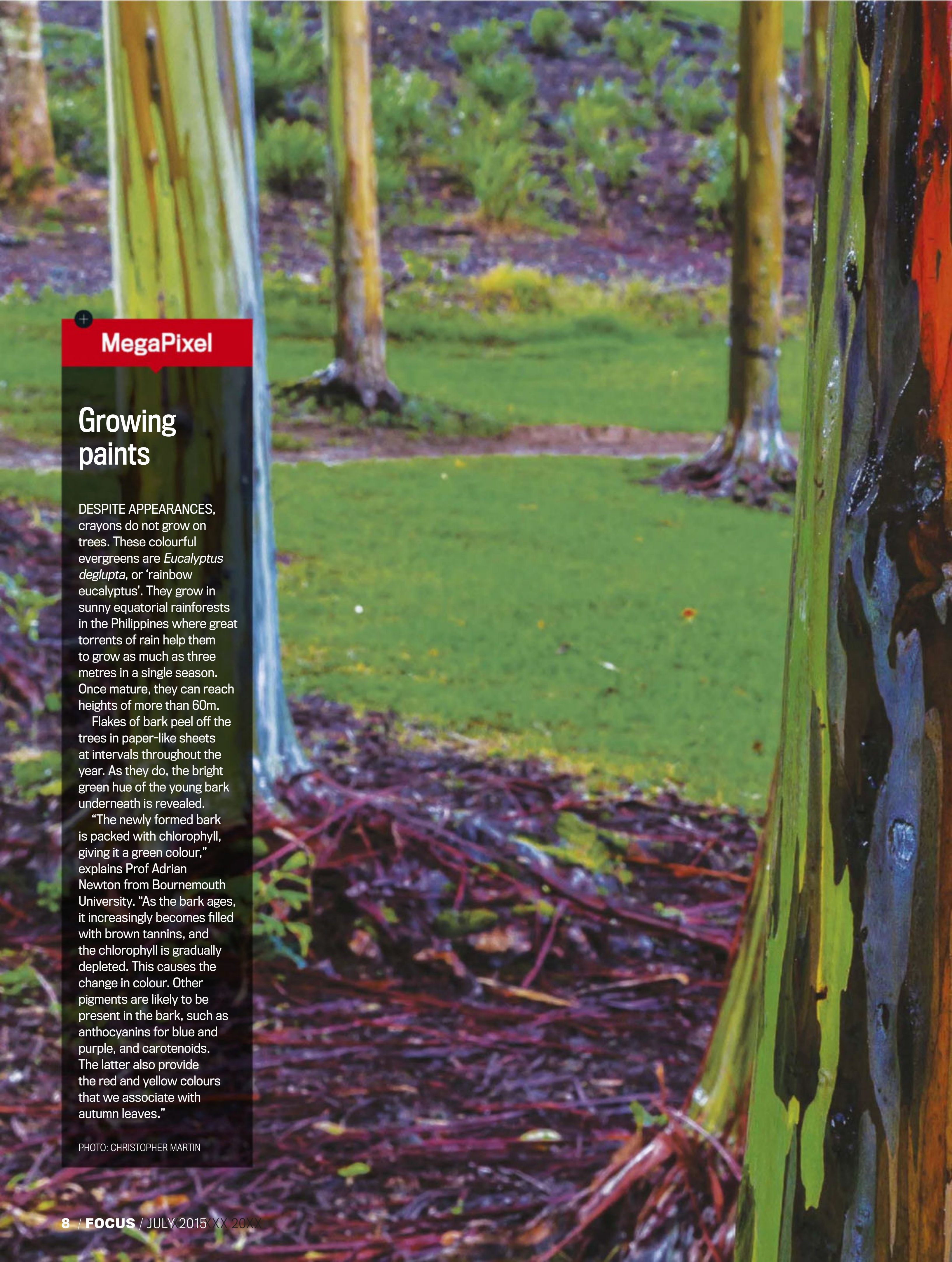
The 400m underpass opened in January and features multicoloured stripes throughout. While there is no doubt that it looks incredible, the spectrum of colours serves a serious scientific purpose: it helps drivers' eyes adjust to the changing light as they enter and exit the tunnel.

"Our eyes are better at seeing bluer colours in dim light," explains Ananth Viswanathan, consultant ophthalmologist at Moorfields Eye Hospital.

"This is because our eyes have two main types of light-sensitive cells – cones for bright light and rods for dim light. The cone system is better at longer red wavelengths whereas the rod system is better at shorter blue wavelengths.

"Having bluer colours in the central dimmer section of the tunnel make sense as colour vision changes at different light levels," he adds.

PHOTO: CORBIS



MegaPixel

Growing paints

DESPITE APPEARANCES, crayons do not grow on trees. These colourful evergreens are *Eucalyptus deglupta*, or 'rainbow eucalyptus'. They grow in sunny equatorial rainforests in the Philippines where great torrents of rain help them to grow as much as three metres in a single season. Once mature, they can reach heights of more than 60m.

Flakes of bark peel off the trees in paper-like sheets at intervals throughout the year. As they do, the bright green hue of the young bark underneath is revealed.

"The newly formed bark is packed with chlorophyll, giving it a green colour," explains Prof Adrian Newton from Bournemouth University. "As the bark ages, it increasingly becomes filled with brown tannins, and the chlorophyll is gradually depleted. This causes the change in colour. Other pigments are likely to be present in the bark, such as anthocyanins for blue and purple, and carotenoids. The latter also provide the red and yellow colours that we associate with autumn leaves."

PHOTO: CHRISTOPHER MARTIN

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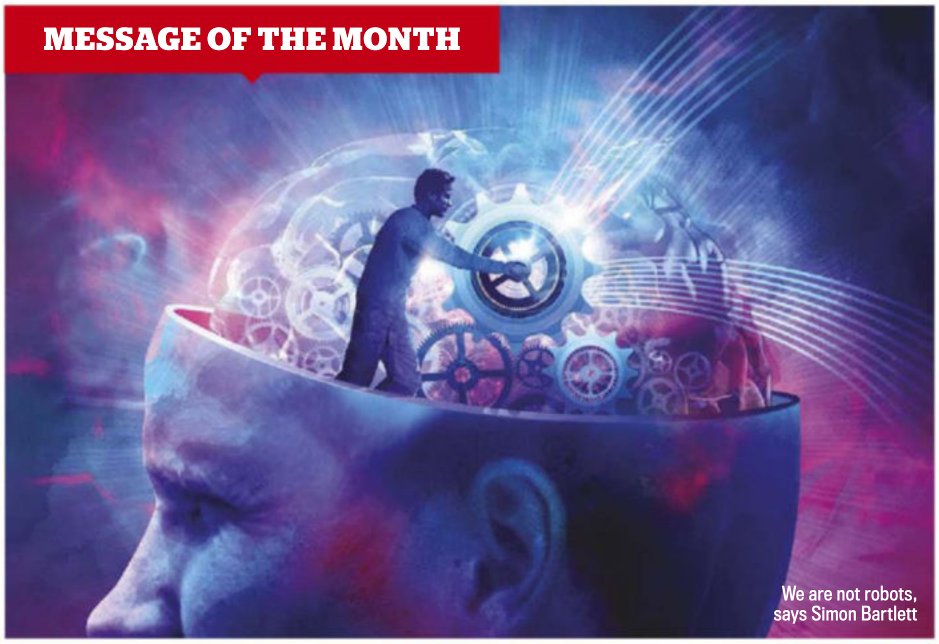

We are not robots, says Simon Bartlett

Of course we have free will!

I APPROACHED THE free will article (June, p32) with interest. I read the book *My Brain Made Me Do It* when *Focus* recommended it a couple of years ago and found it quite persuasive in its pro-free will argument. Like many, I confess to finding the notion that we are automata more than a little distasteful.

Putting that aside – as best as I can, and assuming I am actually free to do so – I was intrigued by the potential explanation that the brain activity used as evidence against free will might actually be *preparation* for a decision, rather than a decision itself. I was reminded that my smartwatch informs me of an incoming call before the phone seems to register it, but this does not mean that the watch is informing the phone – that's just how it seems, using the senses I have to perceive it with. Something similar might be going on within our skulls.

I also thought that the 'no free will' proponents quoted at length were unconvincing. The neuroscientist merely offered 'opinions held by some' as well as his own, and then leapt straight to proof. And the magician seemed to be stating that, because he can trick you into believing you made a choice of your own by using sleight of hand, free will therefore does not exist. This is risible, logically speaking. Now, how long should I navel-gaze about whether my pressing the send button is inevitable?

Simon Bartlett

Write in and win! The writer of this issue's Message of the Month wins a Fugoo Style Bluetooth speaker worth £150. Water-, mud- and drop-proof, the speaker is ideal for festivals and camping, running for up to 40 hours on one charge and boasting 360° sound. **fugoo.com**

PHOTO: ANDY POTTS

More free will

Thanks for an interesting summary piece on the state of thinking about free will. I continue to think that I have some. Experiments such as those by Libet appear to me to be more to do with reaction time. I draw a distinction between making what I continue to call a conscious decision – say to buy the latest edition of *Focus* after a browse – as distinct from pounding the car's brake pedal if a pedestrian suddenly steps onto the road. In the latter case, I am quite happy that my subconscious mind beats my conscious mind to it.

Returning to buying *Focus*, I typically dispose of the leaflet which urges me to subscribe, because I prefer to browse and make a conscious decision. The leaflet-disposal action is probably pre-programmed, driven by the subconscious.

Jim Stark

Your subconscious is letting you down there, Jim. Subscribing is much cheaper than buying Focus *in the shop! –* ***Ed***

Killing machines

Regarding the story '*Terminator*-inspired 3D printer turns liquids into personalised prosthetics' (June, p26), this revolutionary method of making prosthetics is a leap forward in technology and a way of saving and increasing lives. The faster we learn about this technology, the quicker we can build parts for all sorts of things.

But like all new technology, there's bound to be someone out there looking at this tech for a more destructive force. We have already seen guns made like this, but what next? The sum of the human mind for destruction outweighs the thoughts of the good we could do with it. Will we soon see 3D-printed triggers for bombs? The more ingenious we get, the more we tend to find ways of killing.

Terrorism comes in all manner of forms these days: perhaps 3D terrorism will be the next.

Terry Bradley, Milton Keynes

Liquid 3D printing

Mega eruption

I enjoyed your article on Tambora, the volcanic eruption (May, p60), but I felt there was one cultural result of the eruption conspicuously absent from it: the invention of the bicycle, or at least something that would become a bicycle!

The dandy horse, an early incarnation of the bicycle, was developed by Karl Drais, a German farmer, in 1817. His horses were starving due to the poor crops caused by 'the year without summer', so Drais set about developing an alternative method of transport – the dandy horse.

Tambora truly is a remarkable volcano!

Felix Robertson

The dandy horse

Safer syringes

I was delighted to read about Marc Koska's invention of the K1 syringe (David Shukman, May, p21), which automatically disables if someone tries to refill it because the plunger snaps off. This will be a great step forward in preventing the spread of bacterial and viral diseases in those parts of the world where syringe reuse is sadly all too common, noting that these syringes are about the same to buy as the 'normal' ones.

However, the syringe is only part of the problem – unless it was to come with a non-detachable needle. Sharing/reusing needles is responsible for the spread of disease, especially viruses such as HIV and Hepatitis B and C etc. The picture of Marc holding one of his syringes, however, shows the syringe armed with what looks like a standard detachable 'No 1 Green' needle.

Hopefully by now Marc will have addressed this problem, together with the problem of the safe disposal of needle and syringe after use.

Dr Bill Jones, Leeds

Plastic recyclers

In your article 'Drowning in plastic' (April, p60) you did not mention the pioneering achievements of the individuals, institutions and companies who are creating fuel from used and spent plastics, such as Cynar, Envion Inc, Polymer Energy Company, Plastic2Oil, Polygreen and Ecotech Recycling Social Enterprise Ltd. The article only tells of the negative side of the problem we have created. Why not report on what is being deployed to tackle it? Maybe I should mention it to my local council, as the story seems to be circulating that they are burying the plastic they collect.

Phil O'Hare

Making fuel from plastic

PHOTO: GETTY, KOBAL COLLECTION, CORBIS

Personal tricorder

To say the thermometer was the last innovation in home health tracking ('Can we build a personal tricorder?', May, p54) is simply untrue. 24-hour remote monitoring of ECG and blood pressure has been in practice for years.

While Mr de Brouwer may be convinced the potential for Scanadu is limitless, I fail to see any real innovation. Unlike the Q-POC, the data Scanadu obtains is easily collectable and of limited value. Admittedly, a user-friendly device makes measuring vital signs easier. In this respect Mr de Brouwer has replaced the lead thermometer with a digital one.

Mr de Brouwer erroneously conflates having more data with having more knowledge. For any real world applications, the Scanadu must prove itself either more accurate or much cheaper than existing methods.

Ashraf Abbas

The real McCoy

A waste of time?

Bulletproofing pointless?

Your article on the science of bulletproof materials showed only one thing: that the world's best scientists are pitted against each other in a pointless race. New high-tech bulletproof materials are matched by new high-tech, armour-piercing bullets. Without irony, the author even pointed out that the same military research organisation is creating both the next-generation lethal weapons, and the bulletproof materials to stop them.

Alex Randall, Machynlleth

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p18

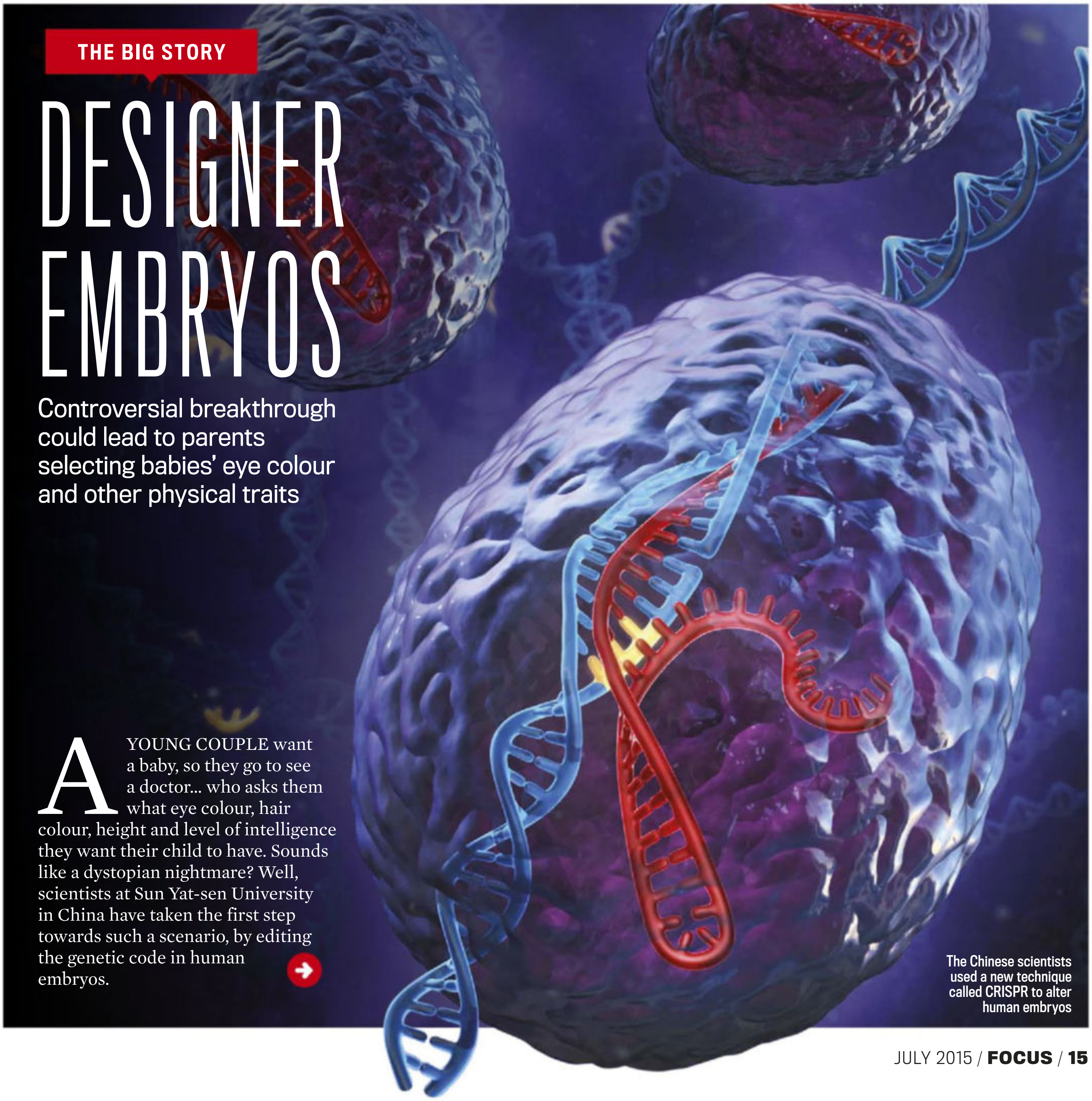
DAVID SHUKMAN
Why air pollution is a growing problem worldwide, and not just in China

pXX

BAT FLIGHT EXPLAINED
How bats perform their in-flight acrobatics is a mystery no longer

p24

VOLCANIC PLANET
Why exoplanet 55 Cancri e has astronomers all in a lava



THE BIG STORY

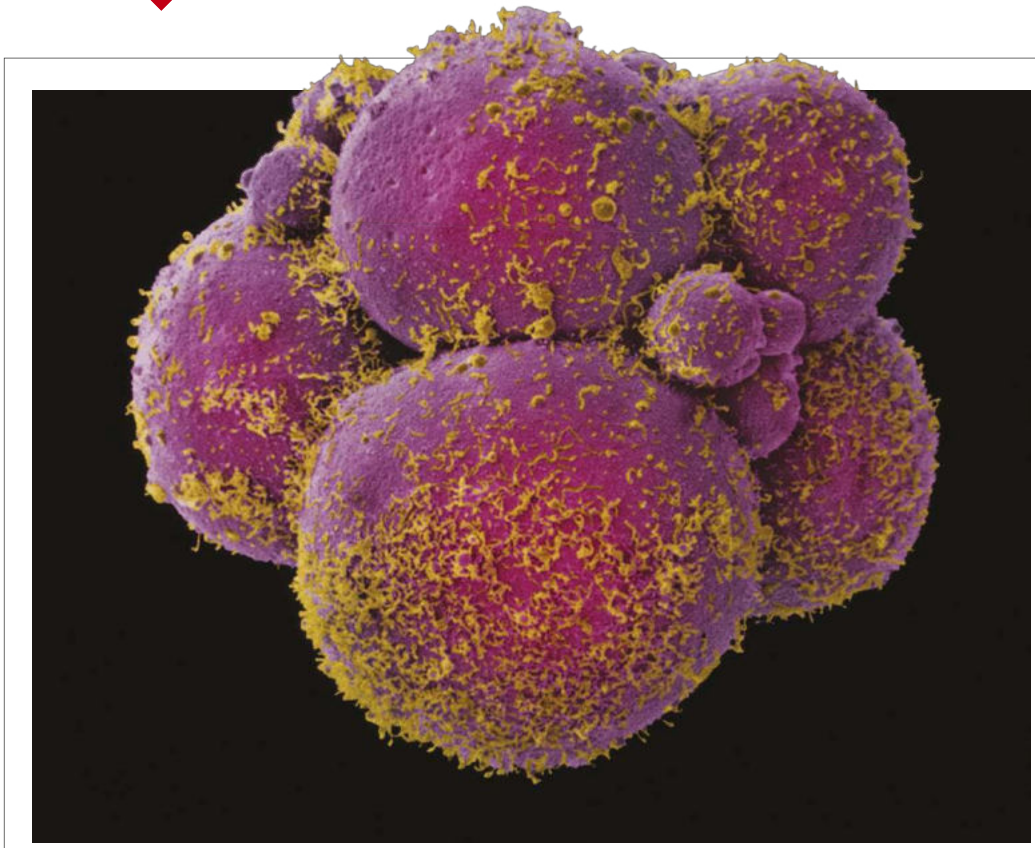
DESIGNER EMBRYOS

Controversial breakthrough could lead to parents selecting babies' eye colour and other physical traits

A YOUNG COUPLE want a baby, so they go to see a doctor… who asks them what eye colour, hair colour, height and level of intelligence they want their child to have. Sounds like a dystopian nightmare? Well, scientists at Sun Yat-sen University in China have taken the first step towards such a scenario, by editing the genetic code in human embryos. ➔

The Chinese scientists used a new technique called CRISPR to alter human embryos

PHOTO: STEPHEN DIXON/BROAD INSTITUTE



A human embryo three days after fertilisation. At this stage, it consists of just eight cells

They took embryos gathered from a fertility clinic, and used a technology called CRISPR to remove the gene responsible for a serious blood disorder. The technique takes molecules ordinarily used by bacteria to fight viruses and uses them to 'cut' specific genes out of a genome. It has previously been used successfully in mice and monkeys.

The embryos used in the work were incapable of developing into live foetuses, but the research has proved controversial in the scientific community, with some going so far as to call for a worldwide ban on using the technology on humans. However, not everyone thinks this is a good idea.

"I disagree with a moratorium, which is in any case unlikely to work well," said the Crick Institute's Robin Lovell Badge. "Indeed, I am fully supportive of research being carried out on early human embryos *in vitro* – especially on embryos that are not required for reproduction, and that would otherwise simply have been discarded."

In addition to the moral issues raised, there are also concerns over the effectiveness of the procedure. Of the 86 embryos used, only 71 survived the procedure. Perhaps more worryingly, even when the correct gene was successfully removed the researchers often created new, unwanted genetic modifications as a side product.

"Altering genes in human embryos can have unpredictable effects on future generations," said Dr Yalda Jamshidi, Senior Lecturer in Human Genetics, St George's University. "Future research on the technique may improve the accuracy and efficiency; however, scientists still don't fully understand the role of the DNA, and all of its genes. It is therefore impossible to assess the risks from mistargeted changes in the DNA sequence, which would affect both the treated embryo and any future generations."

As gene editing methods become ever simpler and more widely available, it's likely this debate will continue for some time.

TIMELINE

A history of genetic breakthroughs

1953

Francis Crick and James Watson discover the double helix structure of DNA. They win the 1962 Nobel Prize in Medicine for their efforts.

1976

Frederick Sanger and Charles Coulson devise a method for sequencing DNA. They name it the Sanger Coulson technique.

1997

Ian Wilmut from the Roslin Institute in Scotland creates Dolly the sheep, the first ever animal to be cloned. Dolly dies of a lung condition seven months later.

2003

The Human Genome Project successfully maps all of the genes in the human genome, the conclusion of over a decade's research.

GOOD MONTH/ BAD MONTH

It's been good for:

OFFICE WORKERS

THERE'S BEEN A lot of talk recently suggesting that sitting down for long periods is playing havoc with our health. Now, a team in Utah have found that getting up off your behind and walking for just two minutes every hour can counteract some of the negative effects.

HAY FEVER SUFFERERS

ITCHY EYES, RUNNY nose, constant sneezing… hay fever can make the summer nigh-on unbearable for some of us. However, a team at Vanderbilt University in Tennessee, USA may have found a solution: probiotic yoghurt. They say the 'friendly bacteria' in such yoghurts may help to ease the symptoms of allergies.

It's been bad for:

HANDSOME MEN

GUYS, EVER WISHED you were as good-looking as Brad Pitt or George Clooney? You might want to think again. Handsome men are less likely to be given jobs, a study at the University of Maryland has found. The effect is due to handsome men being perceived as more competent, which means they're seen as a threat by managers.

BEATLES FANS

THE BEATLES MAY have been given too much credit for their part in the US musical revolution of the 60s, say researchers at Queen Mary University. They argue that similar sounds were already in motion before The Beatles arrived Stateside. "They didn't spark a revolution, they joined one," they say.

PHOTO: SCIENCE PHOTO LIBRARY, ISTOCK, PRESS ASSOCIATION, GETTY

The ground breaking new x40 from Blue Aura

Always striving to innovate, Blue Aura introduces a new loudspeaker category, Stereo Bluetooth tower speakers

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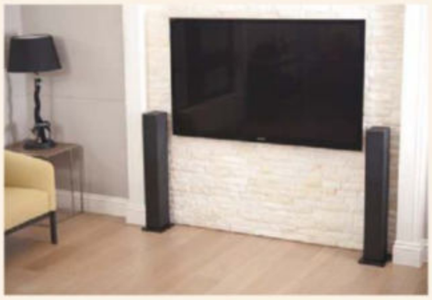

Now being demonstrated at the following stores: Sevenoaks Sound & Vision Chelsea, Adams & Jarrett St Leonards on Sea, Home Media Maidstone Kent, Lintone Audio, Gateshead Sound Academy, Bloxwich

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Where's worst for pollution?

DAVID SHUKMAN

The science that matters

Smog is an issue in big Chinese cities, from Ürümqi in the west to Qingdao in the east (pictured)

PHOTO: PRESS ASSOCIATION

THE AIRPORT TANNOY announcement confirming a delay to our flight mentioned 'weather conditions' as the cause. We were in the western Chinese city of Ürümqi, and what looked like fog blanketed the runway. But it wasn't fog. It was something much denser and more toxic, a cloud of pollution, and it paralysed the airport for hours. Step outside and the smell was unmistakable: acrid but also slightly sweet.

China has attracted the most headlines for the appalling state of its air. In some cities, readings for key pollutants go far beyond World Health Organization limits and reach the highest point on the scale. But air quality is a problem that afflicts cities around the world: Delhi now has the unenviable title of being the world's worst. And while Britain's air is far cleaner than in the days of the 'pea soup' smogs that gripped London until the 1950s, there is still a problem. In one form of pollution, nitrogen dioxide, a dozen British cities have breached EU standards for years.

Since I started reporting on pollution, I've become far more sensitive to it. Film beside a major road for more than a few minutes and you can't miss the odour. Wash your hands afterwards and the dirt in the basin can be shocking. Most shocking of all was visiting a pollution monitoring station in central London and holding a pair of filters: one was new and white, the other had been sampling the air for 24 hours and was dark grey. That grey is in the air we breathe.

Researchers are getting better at working out where this stuff is coming from. Most UK pollution is homegrown, but a lot also blows in from the Continent – a mix of gases and microparticles produced by everything from Parisian traffic to German farmers spraying their fields. The evidence about health effects is mounting up, too. Pollutants can enter the lungs and the bloodstream, and are linked to respiratory and cardiovascular conditions. In Britain, pollution causes an estimated 29,000 extra deaths every year, and a forthcoming study may raise that estimate.

One piece of advice from pollution scientists: don't stand beside busy roads any longer than you have to.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

WHO'S IN THE NEWS?

Alex Zhavoronkov

Director of the Biogerontology Research Foundation

Bio-what was that again?
Biogerontology. Essentially, it's the study of the biological aspects of ageing, otherwise known as 'senescence'.

Right. What's he said or done to get people talking?
Zhavoronkov has raised a few eyebrows by claiming publicly that he, as well as many others, will live to be 150 years old.

How so?
He argues that current advances in biochemical technologies can keep us healthy and youthful until future developments in regenerative medicine and gene therapy further extend our lifespans. He also says that, historically, many people have lived beyond 100, despite enduring tougher times than we are currently going through.

So what does he suggest we should do to live longer?
Zhavoronkov recommends that we should prioritise health and knowledge over material assets, monitor our cell counts and blood biochemistry, store tissue samples in a biobank for future access, and take 'geroprotector' drugs. He practises what he preaches, too, popping more than 100 pills a day.

Feed your mind

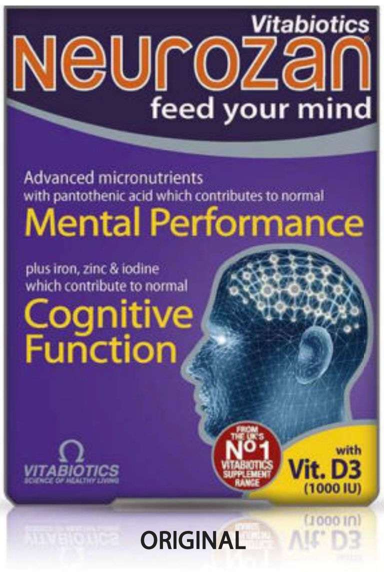
Micronutrients with iron, zinc & iodine, which contribute to normal cognitive function

Neurozan® is an advanced, comprehensive formula to help safeguard your daily intake of essential vitamins and minerals. Including iron, zinc and iodine which support normal **cognitive function** and pantothenic acid which supports normal **mental performance**.

Neurozan® Original contains a specially developed combination of nutrients and is certified by ***Food For The Brain***.

Neurozan® Plus dual pack provides even greater nutritional support with high purity Omega-3 from Norway. 🇳🇴 DHA helps to maintain normal **brain function**[†].

So if you're looking for a supplement that's different, keep *Neurozan®* in mind.


Vitabiotics
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Mental Performance
plus iron, zinc & iodine which contribute to normal
Cognitive Function
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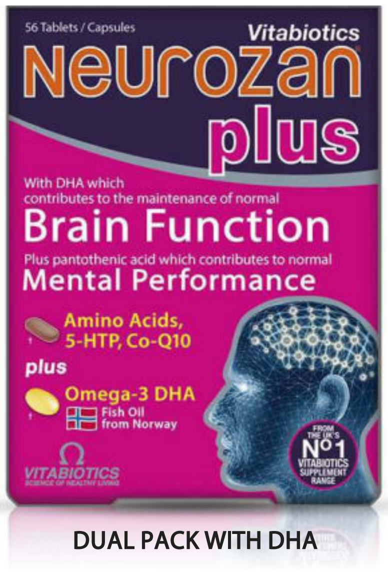
56 Tablets / Capsules
Vitabiotics
Neurozan
plus
With DHA which contributes to the maintenance of normal
Brain Function
Plus pantothenic acid which contributes to normal
Mental Performance
Amino Acids, 5-HTP, Co-Q10
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VITABIOTICS
SCIENCE OF HEALTHY LIVING

[†]A beneficial effect is obtained with a daily intake of 250mg DHA. *Nielsen GB ScanTrack Total Coverage 52 w/e 31 Jan 2015.

ADNEUCONP 16-03-15E

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10

Solar storage material

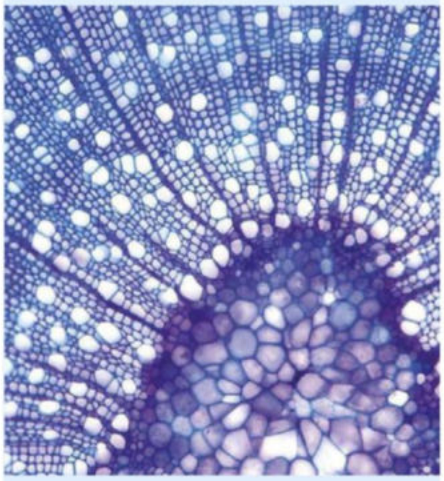
University of Copenhagen researcher Anders Bo Skov shows off the new molecule

IMAGINE CARRYING SUNSHINE in your pocket. Danish researchers are developing molecules known as Dihydroazulene-Vinylheptafulvene that store energy from the Sun by changing their shape, and release it when they change back. The system isn't particularly efficient, but with further refinement it could prove to be an environmentally friendly alternative to current lithium-ion batteries, the researchers say.

9

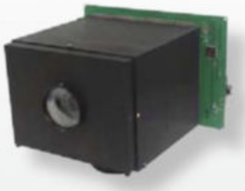
Making trees grow faster

MIGHTY OAKS FROM little acorns grow, the old saying goes. The only trouble is that it's a very slow process. Now, a team at the University of Manchester has identified two genes that are able to increase the growth rate of a poplar tree by speeding up cell division in the stem. ~~The work could increase supplies of renewable resources and help trees cope with the effects of climate change.~~


A section of poplar tree with its cells modified

8

Self-powering camera


Forget never lying – this camera never runs out of battery power, either

CAMERAS that run out of battery just as you're about to take a snap may soon be a thing of the past. A team at Columbia University has created a pixel that can harvest the energy of the light that falls on it, as well as measuring it to create an image. Currently the camera can produce one image per second, indefinitely, in a well-lit room. ~~Eventually the technology could lead to cameras that can function with no need for external power,~~ the researchers say.

7

Centimetre-accurate GPS

IF YOUR SAT-NAV has ever led you into a muddy field, read on. Researchers at the University of Texas have built an inexpensive consumer GPS system that's 100 times more accurate than its current equivalent. The GRID system reduces location errors from the size of a large car to the size of a pound coin. ~~It could be used for delivery drones, self-driving cars, and even virtual reality gaming.~~

The system uses an inexpensive receiver to harvest accurate location information from antennas found in mobile phones.

6

An end to hunger pangs?

IF YOU FIND that extra slice of cake too hard to resist, blame your AGRP neurones. Researchers at Howard Hughes Medical Institute found they generate negative feelings that cause us to seek food. With further study, the researchers say they may be able to manipulate this process and put an end to hunger pangs.

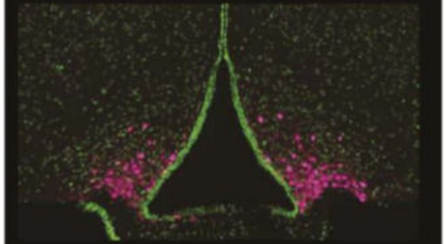

AGRP neurones in the brain manage feelings of hunger

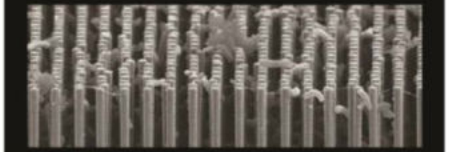
PHOTO: UNIVERSITY OF COPENHAGEN, PROFESSOR SIMON TURNER, ALTERMUNE TECHNOLOGIES, PETRA DITSCHE/UW, NIDDK.NIH.GOV, COLUMBIA ENGINEERING

5 The flexible robots are coming!

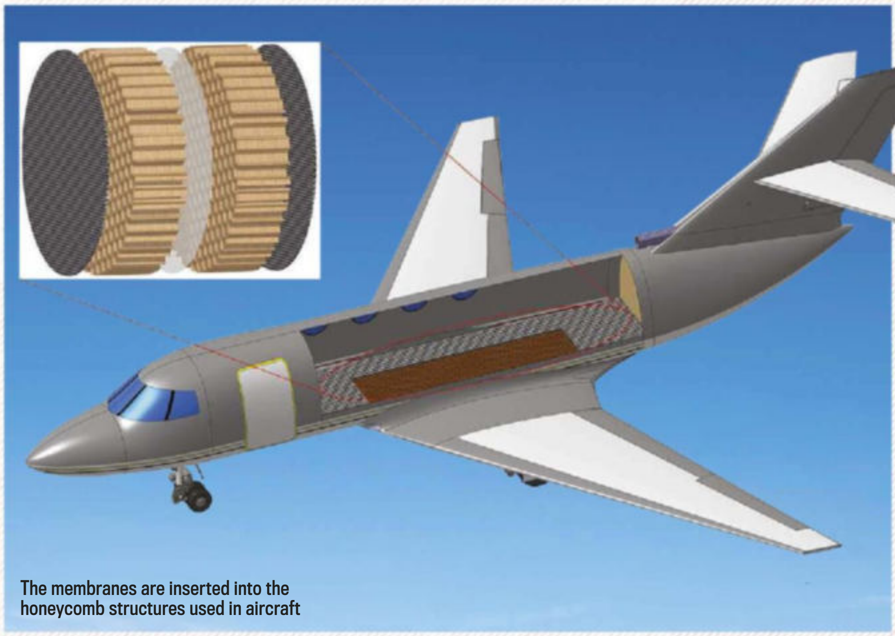
THE DAYS OF stiff, immobile robots may soon be numbered. A team at the University of Pittsburgh has designed a synthetic polymer gel that mimics *Euglena mutabilis*, a single-celled, pond-dwelling organism. The gel can change shape and move using chemical energy. Scaled up, the gel could be used to create robots that are lighter and have an improved range of motion.

4 Artificial photosynthesis

BIODEGRADABLE PLASTICS can now be made using artificial photosynthesis. The system, developed at the University of California, is made of tiny bacteria-coated wires that absorb solar energy and use it to convert CO_2 into acetate.



Those bacteria-coated nanowires up close



The membranes are inserted into the honeycomb structures used in aircraft

3 Quieter flights

AS ANYONE WHO'S ever tried to get 40 winks during a long haul flight knows, riding in aeroplanes can be a noisy experience. Help may be on the way, however, in the form of a thin rubber membrane that's been designed by a team at Massachusetts Institute of Technology.

The material can be placed into the cabin walls and could block 100 to 1,000 times more sound energy when installed. It works by causing soundwaves created by airflow on the outside of the aeroplane to bounce off, rather than pass through into the cabin.

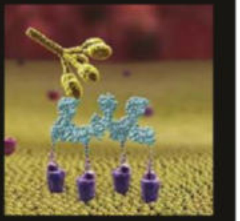
2 Safer suction

The clingfish got its name for a very good reason

MEET THE NORTHERN clingfish, a tiny fish with serious suction power. A team at the University of Washington is investigating the biomechanics of how its suction force can hold up to 150 times its own bodyweight even in wet, slimy environments. The key is an elastic disc on their bellies that is covered in a microscopic hair-like structure. Similar technology could lead to a bio-inspired device that could stick to organs or tissues without harming the patient, or be used to tag whales and track them, the team says.

1 'Homing beacon' to beat bacteria

A MOLECULAR 'HOMING beacon' that attracts antibodies has been developed and used to 'tag' bacteria by a team at the University of California. One end of the molecule has a DNA aptamer that attaches to an invasive bacteria, while alpha-Gal, a sugar molecule, is at the other end. The alpha-Gal triggers the release of antibodies which then attack the bacteria. The technique may eventually be used to attack any type of bacteria or virus, or perhaps even cancer cells, researchers say.



Homing molecules at work

ZOOLOGY

Bats' extraordinary flying skills revealed

The mystery of bats' in-flight acrobatics has been solved! Next month: where socks go

WHEN IT COMES to airborne acrobatics there are few animals that can rival the agility of bats. However, quite how they achieve this has so far been a riddle.

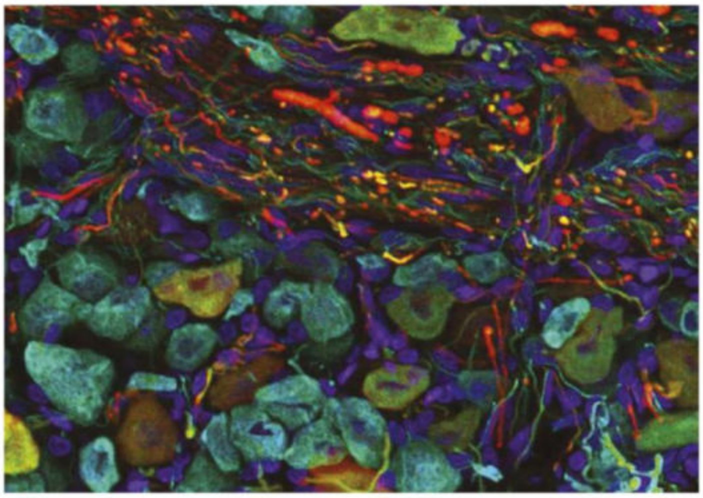
Now, a team at Johns Hopkins University think they have the answer. Touch-sensitive cells clustered around tiny hairs that cover the bats' wings send information about airflow directly to their brains, allowing them to make split-second adjustments in mid-flight.

"Until now, no one had investigated the sensors on the bat's wing, which allow it to serve as more than a propeller, a flipper, an airplane wing or any simple airfoil," said researcher Cynthia F Moss. "These findings can inform more broadly how organisms use touch to guide movement."

The team studied the big brown bat, a common species found throughout North America that's able to fly at speeds up to 32km/h (20mph). They found that the evolutionary process which allowed bats to form wings resulted in unusual tactile circuitry that not only enhances control during flight, but also allows bats to use their wings to climb, cradle their young and capture insects.

They also found that the pattern of nerves in the bats' wings is different from that of other mammals. Neurones within the wings' skin connect not only to the area in the animals' spinal cords that is typically associated with forelimbs, but also to an area normally connected to the trunk.

The findings lay the groundwork for understanding how bats use sensory information to fly with incredible precision in the dark and catch prey in mid-air. Looking further forward, the new knowledge could even lead to engineers one day being able to design aircraft that can manoeuvre around obstacles by adjusting to air turbulence.



Nerve cells on the brown bat's wings connect to more than one area on the animal's spine

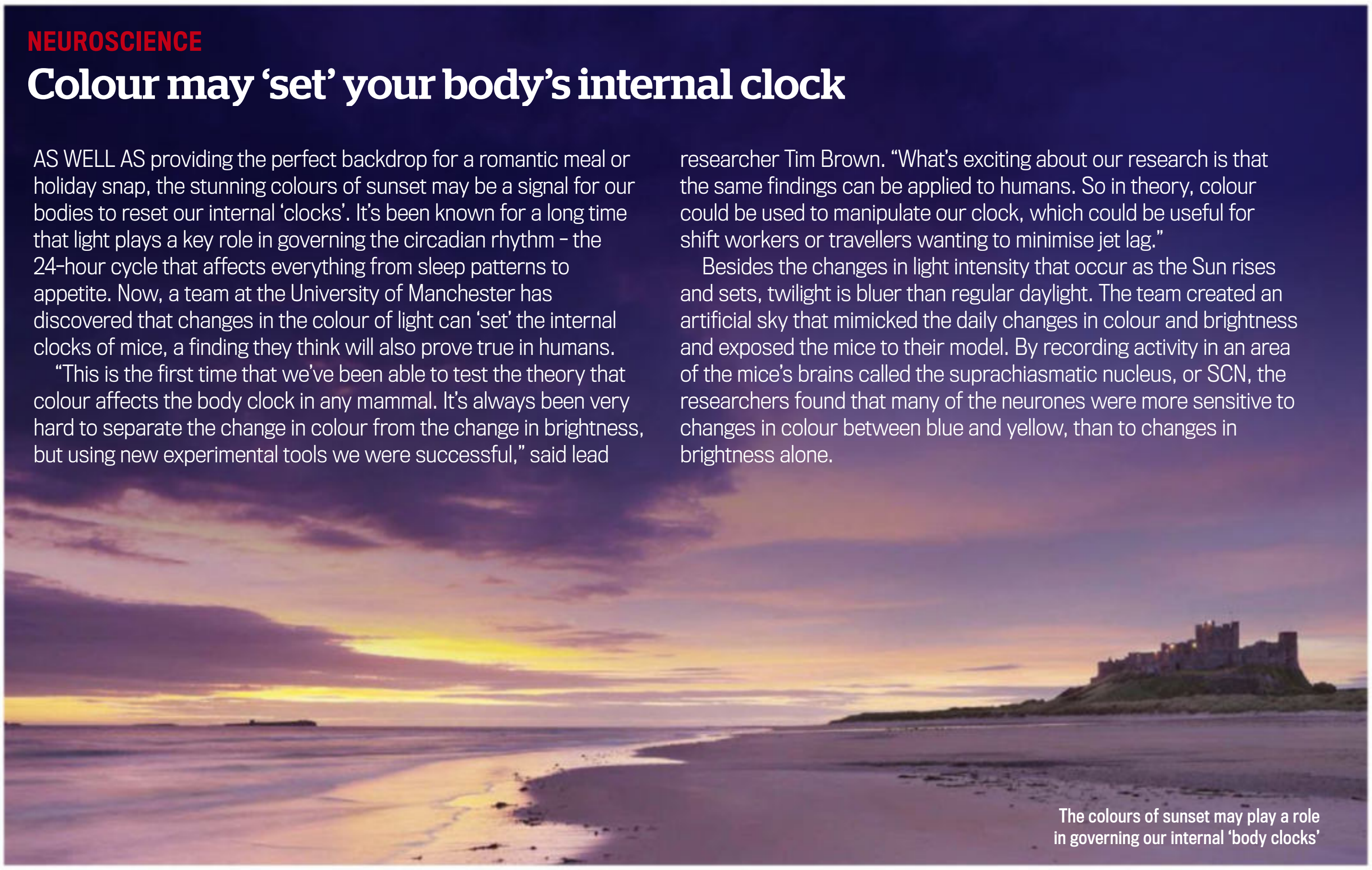
NEUROSCIENCE

Colour may 'set' your body's internal clock

AS WELL AS providing the perfect backdrop for a romantic meal or holiday snap, the stunning colours of sunset may be a signal for our bodies to reset our internal 'clocks'. It's been known for a long time that light plays a key role in governing the circadian rhythm – the 24-hour cycle that affects everything from sleep patterns to appetite. Now, a team at the University of Manchester has discovered that changes in the colour of light can 'set' the internal clocks of mice, a finding they think will also prove true in humans.

"This is the first time that we've been able to test the theory that colour affects the body clock in any mammal. It's always been very hard to separate the change in colour from the change in brightness, but using new experimental tools we were successful," said lead researcher Tim Brown. "What's exciting about our research is that the same findings can be applied to humans. So in theory, colour could be used to manipulate our clock, which could be useful for shift workers or travellers wanting to minimise jet lag."

Besides the changes in light intensity that occur as the Sun rises and sets, twilight is bluer than regular daylight. The team created an artificial sky that mimicked the daily changes in colour and brightness and exposed the mice to their model. By recording activity in an area of the mice's brains called the suprachiasmatic nucleus, or SCN, the researchers found that many of the neurones were more sensitive to changes in colour between blue and yellow, than to changes in brightness alone.



The colours of sunset may play a role in governing our internal 'body clocks'

PHOTO: FLPA, ISTOCK, KARA MARSHALL/COLUMBIA UNIVERSITY

INSIDE SCIENCE

ROBERT MATTHEWS

How a 'crackpot' theory has just been proved correct

ONE CENTURY AFTER a young German scientist tried and failed to convince others of his silly ideas about continental drift, it's his critics that have ended up looking silly.

Back in 1915, Alfred Wegener published *The Origin Of Continents And Oceans*, in which he presented evidence for what is now called plate tectonics. He hoped the book would spark interest among geologists. Instead, they seized on the obvious flaw in the idea: how can continent-sized slabs of rock slide around the Earth?

Wegener was still trying to convince his critics when he died in 1930, aged just 50. He'd put forward some ideas for ways of greasing the movement of continents, but they were dismissed as "utter, damned rot".

Now the mystery has been solved – and it turns out Wegener was on the right track. Using controlled explosions to trigger seismic echoes from deep within the Earth, a team of researchers in New Zealand has recently found that the plates of rock making up the crust sit atop pools of slippery, melted rock around 70-80km down.

So it seems that Wegener wasn't so crazy after all. Geologists had been forced to concede that point back in the 1960s, when analysis of sea floor rock showed continents do move apart – even if no one knew how.

People using the Argument from Omniscience can find themselves on shaky ground

What the new findings, published in *Nature*, really show is the danger of dismissing a theory just because it doesn't fit with current knowledge. This is the Argument from Omniscience: the assumption that just because we don't have an explanation, it means no-one will find one, ever.

That sounds like arrogance to the point of lunacy. Yet you'll find plenty of otherwise rational people wheeling it out to dismiss ideas that they don't like, such as homeopathy. Before some of them start firing off emails demanding my immediate dismissal and execution, I should make clear that the evidence does not convince me either. But sceptics need to stop using the Argument from Omniscience.

> **"I can think of a host of intriguing theories that keep running into the Argument from Omniscience"**

Magnetism, radioactivity, aerodynamics, superconductivity… there's no shortage of phenomena whose reality once defied explanation. Radioactivity once caused huge concern because it seemed to violate the Law of Energy Conservation – until Einstein came up with his famous formula showing how mass can be converted into energy.

Indeed, some of the most intriguing phenomena in science, like anaesthesia, ball lightning and dark energy, are still not fully understood. Fortunately, hard evidence for these emerged fast enough to ensure researchers who take them seriously won't suffer the fate of Wegener. But I can think of a host of intriguing theories in everything from cancer therapy to cosmology that keep running into the Argument from Omniscience: science cannot currently explain them, so it never will.

There are better rules for judging new theories. For example, Ockham's Razor says that the more assumptions a theory makes, the less likely it is to be valid. And science populariser Carl Sagan advocated another rule of thumb: extraordinary claims require extraordinary evidence.

These rules are not always easy to apply, but they do have a solid basis in the mathematics of evidence – which the Argument from Omniscience doesn't. Of course we can't take every idea seriously; there just isn't enough time or money. But Wegener's belated vindication is a reminder that some astounding scientific advances emerge from ideas that are not entirely rock solid. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

ILLUSTRATOR: DALE EDWIN MURRAY

1 MINUTE EXPERT

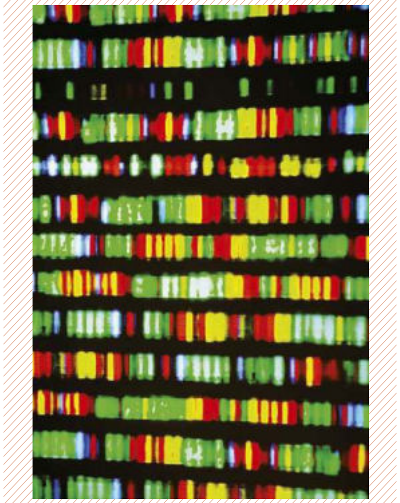
Methyl-adenine

That sounds nasty. What is it?
A sixth DNA base. Maybe.

Hang on, I thought there were only four DNA bases?
That's partly right. DNA is the main component of our genetic material and is made up four 'bases': adenine, cytosine, guanine and thymine, or A, C, G and T. These can combine in thousands of ways, giving rise to the incredible genetic variation we see in living beings.

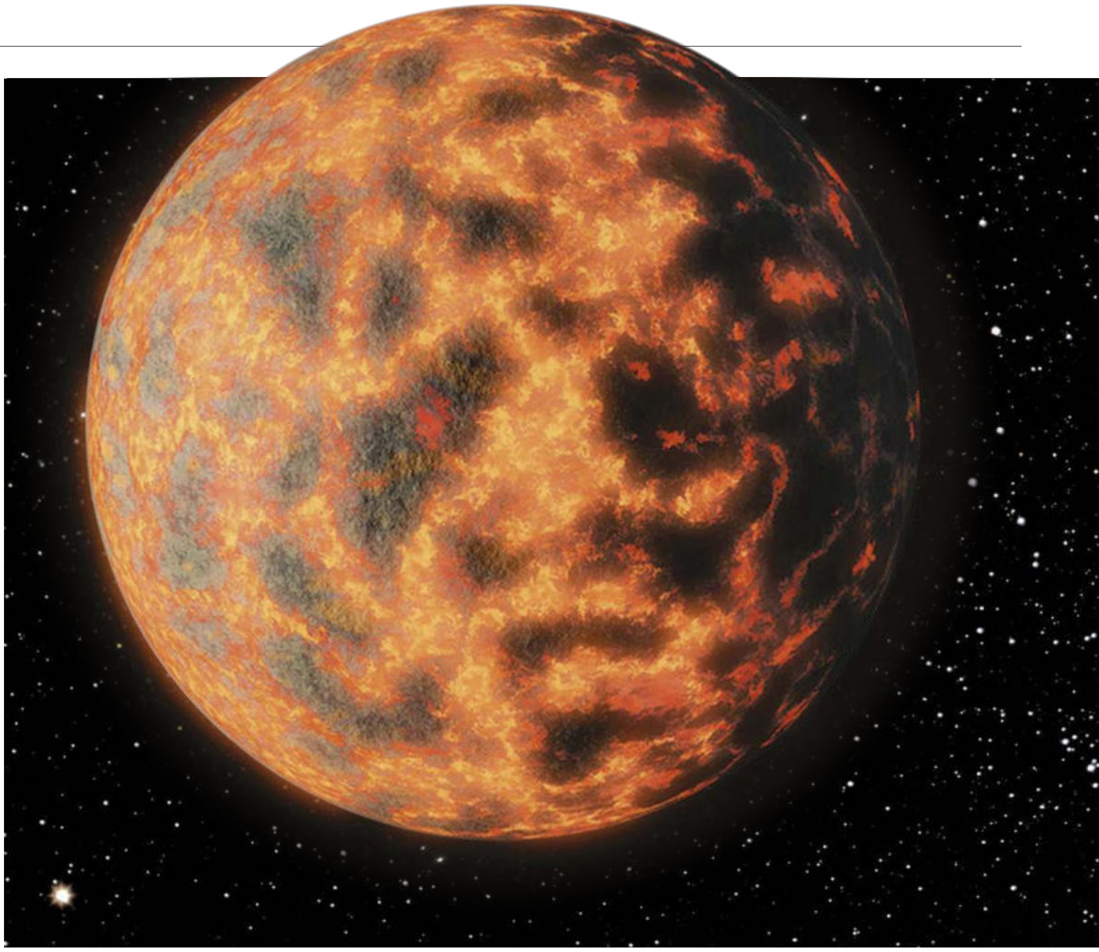
So what's all this business about other bases?
In the 1980s, a fifth base, methyl-cytosine or mC, was found to exist alongside the classic four. The 'methyl' bit means the cytosine molecule has an extra carbon atom and three hydrogen atoms. It is able to switch genes on or off and is involved in many diseases, including cancer.

...and the sixth?
Now, researchers think methyl-adenine, mA, may also play a role in the expression of certain genes. However, further study is needed to determine exactly what it does.



The structure of DNA may be more complex than was previously thought

PHOTO: NASA/JPL-CALTECH/R HURT, RICE UNIVERSITY, STAFFAN LARSSON, ISTOCK



SPACE

Astronomers find volcanic planet

IT'S PERHAPS THE closest thing to Mordor ever discovered: researchers at the University of Cambridge have observed a planet so teeming with volcanic activity that it can swathe itself in great clouds of ash and smoke.

Using NASA's Spitzer Space Telescope, the team recorded thermal emissions coming from the planet 55 Cancri e. These emissions swung between 1,000°C and 2,700°C over a two-year period.

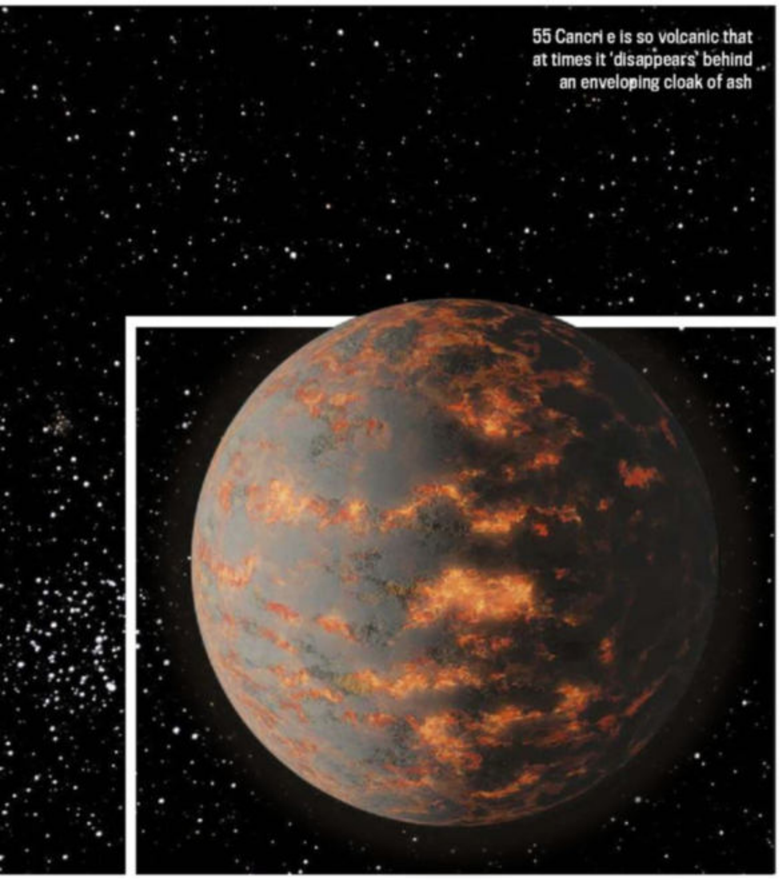
55 Cancri e is a rocky exoplanet about twice the size and eight times the mass of Earth. The so-called 'super Earth' is found 40 light-years away, in the constellation of Cancer, and orbits so close to its parent star that a year lasts just 18 hours. The planet is tidally locked, so it doesn't rotate like the Earth does – instead there's a permanent 'day' side that receives all of the radiation from the star, and a 'night' side. Due to its relative proximity to Earth, 55 Cancri e is also among the best candidates for detailed observations of the surface and atmospheric conditions on rocky exoplanets.

THEY DID WHAT?!

Neuroscientists make volunteers 'invisible'

What did they do?
A team at the Karolinska Institutet in Sweden had volunteers wear head-mounted virtual reality displays, set up so that when they looked down at their bodies they saw empty space. They then touched the participants' bodies with a large paintbrush, while imitating the movements with another brush in full view of the subjects. It took less than a minute for the subjects to transfer their sensation of touch to the empty space where they saw the paintbrush move, making them feel as if their body was invisible.

What did they find?
They also got subjects to perform in front of an audience both before and after they underwent the 'invisibility' session. The volunteers' heart rates were



55 Cancri e is so volcanic that at times it 'disappears' behind an enveloping cloak of ash

"This is the first time we've seen such drastic changes in light emitted from an exoplanet, which is particularly remarkable for a super Earth," said researcher Nikku Madhusudhan. "No signature of thermal emissions or surface activity has ever been detected for any other super Earth."

Researchers believe this drastic change in thermal emissions could be due to intense volcanic activity on the surface spewing out huge volumes of gas and dust which sometimes blanket the planet, making it look like a great ball of ash.

"When we first identified this planet, the measurements supported a carbon-rich model," said Madhusudhan. "But now we're finding that those measurements are changing over time. The most recent observations open up a new chapter in our ability to study the conditions on rocky exoplanets using both current and next-generation large telescopes."

lower and they reported feeling less stressed during the performance when they had undergone a short period of 'invisibility' beforehand.

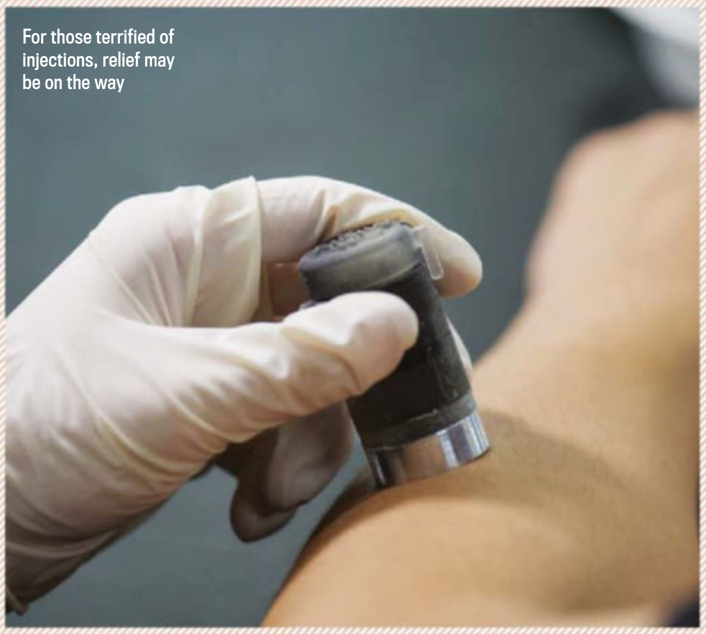
Why did they do that?

The results of the study could be of value in developing new therapies for conditions such as social anxiety disorder, the researchers say.

The VR headset created a sensation of invisibility surprisingly quickly

PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world



For those terrified of injections, relief may be on the way

Pain-free pricks

THOSE WHO DREAD the doctor's needle may soon be in for a nice surprise. Students in the US have created a device that rapidly numbs the skin, reducing the pain of an injection. The three first-year students at Rice University have called their gizmo 'Comfortably Numb'.

It's a 3D-printed, single-use device consisting of two sealed chambers containing ammonium nitrate and water. When the device is twisted, the contents of the two chambers come into contact, triggering an endothermic (heat-absorbing) reaction. Placing the metal device against the patient's skin produces a numbing effect within 60 seconds, after which they can receive a shot painlessly. The invention will be useful for those who are about to receive an injection in a sensitive area.

Patent application underway

No more spoilers

IT'S ALWAYS THE same – you spend ages carefully avoiding details about your favourite TV series, then someone goes and blurts out the killer plot twist on Facebook or Twitter. Well, Google feels your pain. The tech giant has patented a system that will keep track of the films and series that you're watching, flagging up a warning if someone posts something that could include a spoiler. Unfortunately, though, it won't stop your friends from giving the game away in the pub. For that, you'll need gaffer tape.

Patent number: US 9,002,942

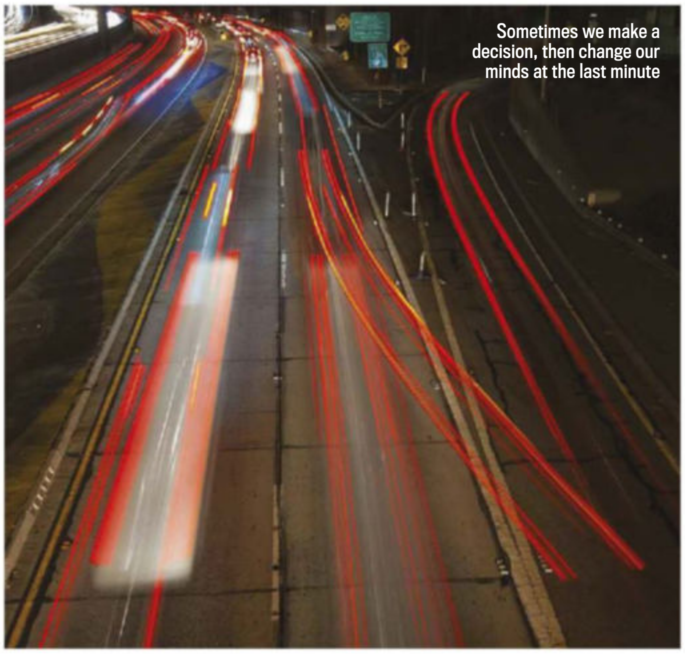
Smart wipers

HERE'S ANOTHER STEP towards making cars fully automatic. Jaguar Land Rover has invented a system that automatically clears the rear windscreen whenever you look in the rear-view mirror. Sensors track your gaze and head movements, triggering an extra wipe of the windscreen when you check your mirror. It'll save you fiddling with the wiper settings, and the window will be free of rain and muck at just the right time. Next up: wipers that don't make that horrible squeak?

Patent application number: US 20150066293

NEUROSCIENCE

Observed: the precise moment the brain makes a decision



Sometimes we make a decision, then change our minds at the last minute

SUNNY SIDE UP or over easy? Train or bus? Cappuccino or latte? Life is full of decisions. Now, researchers at Stanford University have successfully recorded the changes in brain signals that occur when a monkey makes a choice.

The team trained laboratory monkeys to perform a decision-making task that involved choosing between two targets on a computer screen. They then tracked the monkeys' brain signals as the decisions were made. Sometimes the monkeys were able to reach either target, giving them a free choice; at other times one target was blocked, resulting in a forced choice.

By monitoring the monkeys' motor and premotor cortex using electrodes, the team were able to analyse brain activity during each individual decision. In a sense, they were able to read the monkey's mind during the free choices, when each decision may be different.

"We can now track single decisions with unprecedented precision," said Stanford neuroscientist Matthew Kaufman. "Brain activity for a typical free choice looked just like it did for a forced choice. But a few of the free choices were different. Occasionally, he was indecisive for a moment before he made any plan at all, and about one time in eight, he made a plan quickly but changed his mind a moment later."

The work could lead to more effective control algorithms for neural prostheses, which enable people with paralysis to drive a brain-controlled prosthetic limb or guide a neurally-activated cursor on a computer screen.

Matthew Kaufman, monkey mind-reader

MICROBIOLOGY

Microbe may be missing link in the evolution of complex life

IT'S ONE OF the most fundamental questions in science: how did complex life evolve? Now, a team from Uppsala University in Sweden has moved one step closer to the answer after discovering a new group of microorganisms that represents a missing link in the evolution from simple to complex cells.

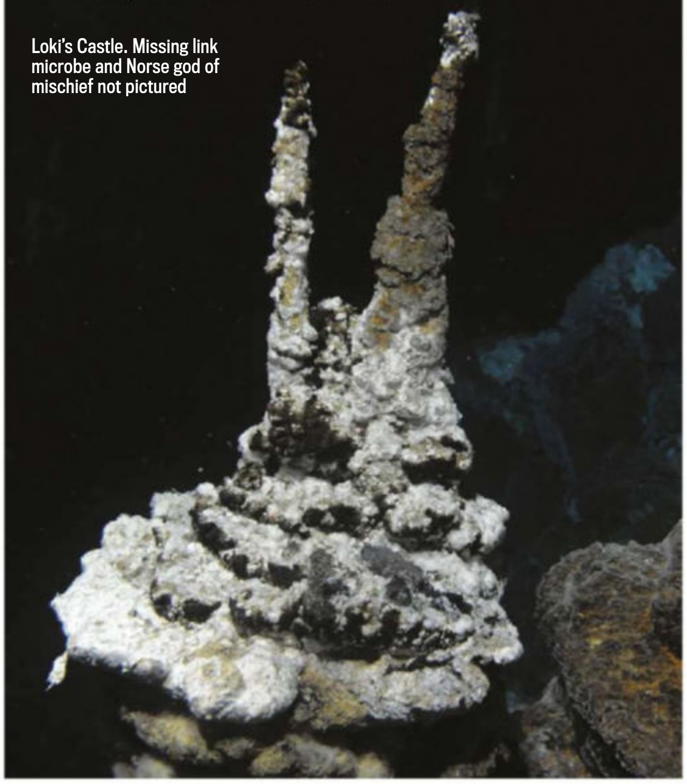
Dubbed *Lokiarchaeota*, or 'Loki' for short, the microbe was found in Loki's Castle, a 2,350m-deep hydrothermal vent located between Norway and Greenland.

All organisms on Earth are either prokaryotes, such as bacteria, which have simple cells, or eukaryotes, such as mammals, which have more complex cells. However, as the two cell types are so different in composition, biologists have long wondered how one evolved from the other.

"The puzzle of the origin of the eukaryotic cell is extremely complicated, as many pieces are still missing. We hoped that Loki would reveal a few more pieces of the puzzle, but when we obtained the first results, we couldn't believe our eyes. The data looked spectacular," says researcher Thijs Ettema. "By studying its genome, we found that Loki represents an intermediate form between the simple cells of microbes and the complex cells of eukaryotes."

Despite having a very simple structure, the microbe was found to share many genes in common with eukaryotes. This suggests cellular complexity emerged in an early stage of evolution, the researchers say. However, further investigation is required to determine what functions the genes perform.

"We are just getting started. There is still a lot to discover, and I am convinced we will be forced to revise our biology textbooks in the near future," says Ettema.



Loki's Castle. Missing link microbe and Norse god of mischief not pictured

PHOTO: SUSANICA TAM, KIM EINAR ANDREASSEN/UIB/UNDERSEA PHOTOS/CENTRE FOR GEOBIOLOGY/UIB

EVERYDAY SCIENCE

HELEN CZERSKI

Why lazy gardeners should start watering their plants

ILLUSTRATOR: ANDREW LYONS

POTTED PLANTS CAN be ungrateful things. I've usually got a bit too much on the go, and the nice thing about plants is that you can get on with being busy for a while and they'll probably still be alive when you come back.

But when you bounce along with your watering can after a period of (let's be honest) neglect, full of good intentions to make it up to them, they often reject your offerings. This week, I noticed the dry soil around the herbs on my balcony, and went out with water to help. But the water sat in jaunty droplets on top of the soil, and as I added more, the droplets joined together and flowed out to the sides, leaving seemingly untouched dry soil in their wake. It's a weird thing to watch, and it only happens when the soil is dry to start with. I've seen this happening for years (I've neglected a lot of plants in my time), but it was only this week that it really occurred to me to wonder what was going on.

With my physicist hat on, it seems that this is what you'd expect from a hydrophobic material (one that repels water). But soil can't be hydrophobic – one of the main reasons that plants can grow in it is that it's fantastic at transporting and holding water. Soil is made up of specks of rock, organic material and microbes mixed together with gaps in between, and water seeps into all those tiny holes and tunnels really easily. Those gaps act like the pores in a kitchen towel soaking up a spill, and water will creep along the surfaces, filling in the gaps as it goes. Any plants parked in the soil will have access to whatever water is nearby, because the soil acts like a sponge and holds the water in.

> **"The molecules are also assembling a reprimand to lazy plant-carers like me. Get that watering can out more often!"**

I didn't give up on watering the parsley, because I know how to get around the problem. You make a little dip in the soil and fill that with water so that it can't run off immediately. And after a few seconds, it seeps in, wets the soil, and then when you pour more water on it's taken up immediately. But this sounds like Catch-22 – if the soil is only hydrophobic when it's dry, how do you get it wet enough to make the problem go away?

After a bit of investigation, I found that the problem occurs when the amount of water in the soil falls below approximately a quarter of the total volume. At this point, the soil particles become coated with lipids and wax that are produced by either the plant or the microbes around it. Oily and fatty substances repel water, so the water droplets just sit on top of the dry and waxy soil. If you get those coatings wet for long enough, they change and the water can touch the minerals or organic matter directly. The uncovered surface can then stick to the water molecules, and the water can begin creeping into the pores and down into the soil. The details of these coatings are still a bit of a mystery, even though it's an important problem for farmers in hot countries. If you have dry, water-repellent soil, the rains may come, but the water will simply run over the top into the nearest stream and be wasted.

It's weird to think of tiny organic molecules shuffling around the soil as it dries out, building up a waxy wall between the soil particles and the air. But as well as constructing a coating, the molecules are also assembling a reprimand to lazy plant-carers like me. Get that watering can out more often! ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series was *Super Senses*

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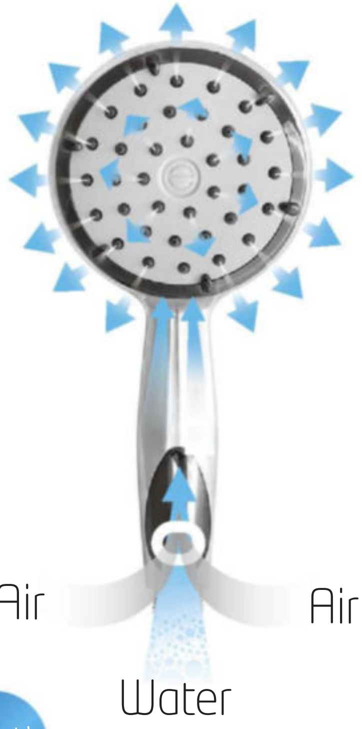

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INTO THE FUTURE

STEPHEN BAXTER

Will high-tech hospitals force doctors out of a job?

SEVENTY YEARS AGO, in June 1945, campaigning was underway in a general election that would elect the first post-war British government. Arguably, the Attlee government's most significant achievement was the establishment of the National Health Service, which was implemented across the UK by 1948. Much cherished and politically divisive, the NHS certainly delivered a revolution in healthcare across Britain.

Today, the march of technology promises – or threatens – to deliver a revolution just as profound. One recent eye-catching example was the kicking of the first ball in Brazil's 2014 World Cup by a paraplegic man in a mind-controlled exoskeletal suit. Such devices hold out great hope for many patients. Work on external prosthetics is underway at Tokyo's University of Science, while a team at the Kentucky Spinal Cord Injury Research Center at the University of Louisville is making progress in crucial human-machine communication interfaces.

Could a robot ever offer the same empathy as a medical professional?

But other medical advances are perhaps more significant, even if they are less spectacular. Thanks to the ubiquity of smart, interconnected devices, the boundary between patient and medical practitioner is dissolving. New technology enables monitoring and diagnostics in the home and even in the body. Already we have apps for smartphones and watches to monitor vital signs like pulse rate and calorie counts. And as foreseen by Greg Bear in his 1990 novel *Queen Of Angels*, a smart lavatory could make good diagnostic use of the large volumes of stool and urine samples you deposit into it every day…

Technology is invading hospitals too, with such innovations as smart bandages with sensors 3D-printed onto the cloth, capable of monitoring vital signs. Meanwhile, an interesting computer program developed at Oxford University is capable of diagnosing some genetic disorders from digital images of faces: an example was a tentative diagnosis of Marfan syndrome, associated with large facial features, based on a photograph of Abraham Lincoln.

> **"Radiologists are being replaced by software. And who needs *Star Trek*'s Dr McCoy when you can have a tricorder?"**

Customised medicine, with treatment based on your personal profile, is in development. A potential problem with this might be a widening health gap between rich and poor – your wealth might some day significantly influence your longevity, if it determines the health options you can afford.

But where is your doctor in all this? Just as automation destroyed jobs on the shop floors and factories, and is now replacing office workers like travel agents and secretaries, even highly skilled medical professions are under threat. Radiologists, for example, are being replaced by pattern-recognition software. As for GPs, who needs *Star Trek*'s Dr McCoy when you can have your own tricorder? As reported in May's *BBC Focus*, the X Prize Foundation has sponsored a $10m competition to develop a handheld device capable of diagnosing 16 specified medical conditions.

There is even a pioneering robot surgical system called Da Vinci, from Silicon Valley firm Intuitive Surgical. But would you trust a robot surgeon? While 'simple' conditions may be treated by smart systems, the human body remains a messy and mysterious object. Anybody who has had experience of a complex medical condition will know how significant a role human judgment plays in most treatments, which is a quality we may still be some time away from automating. And surely patients will always need the human empathy of a good nurse. ■

STEPHEN BAXTER is a science fiction author who has written over 40 books. His latest is *Ultima*, published by Orion

ILLUSTRATOR: ANDY POTTS

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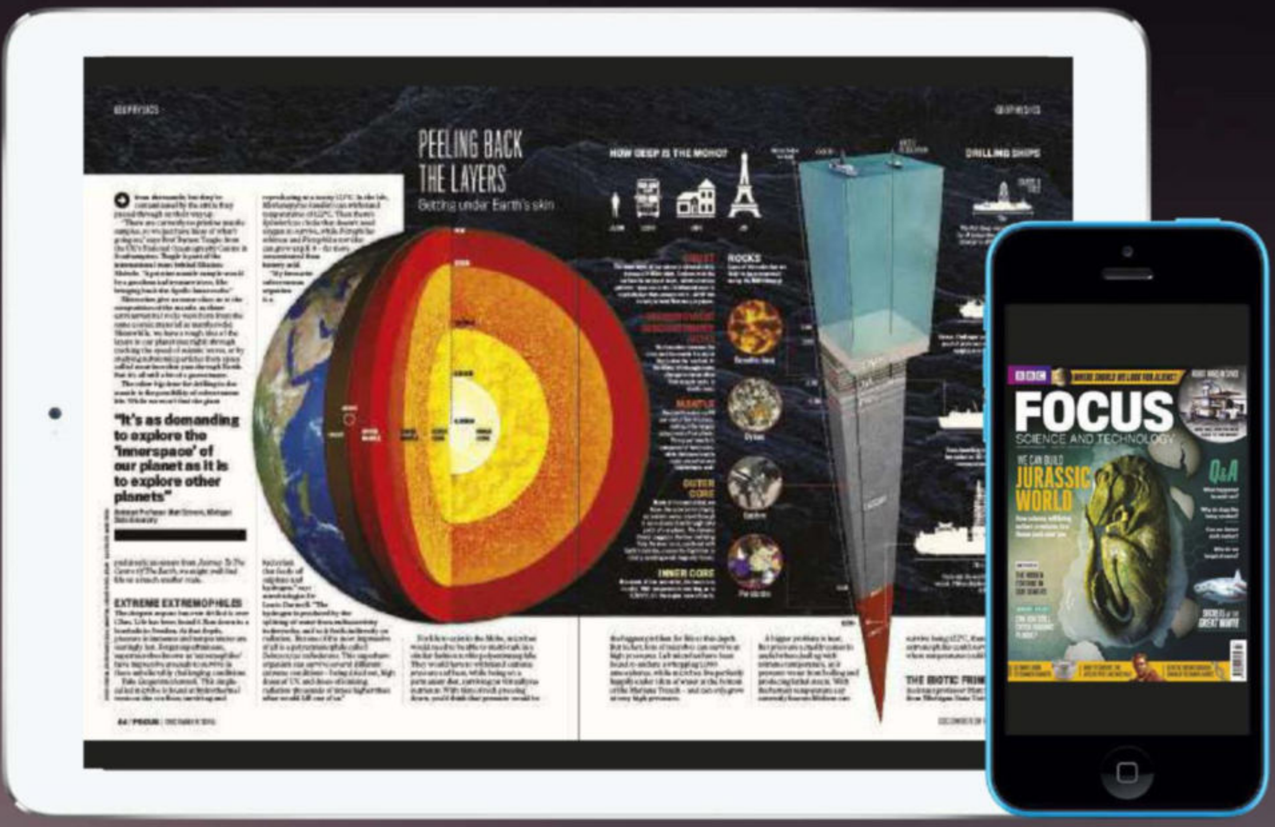
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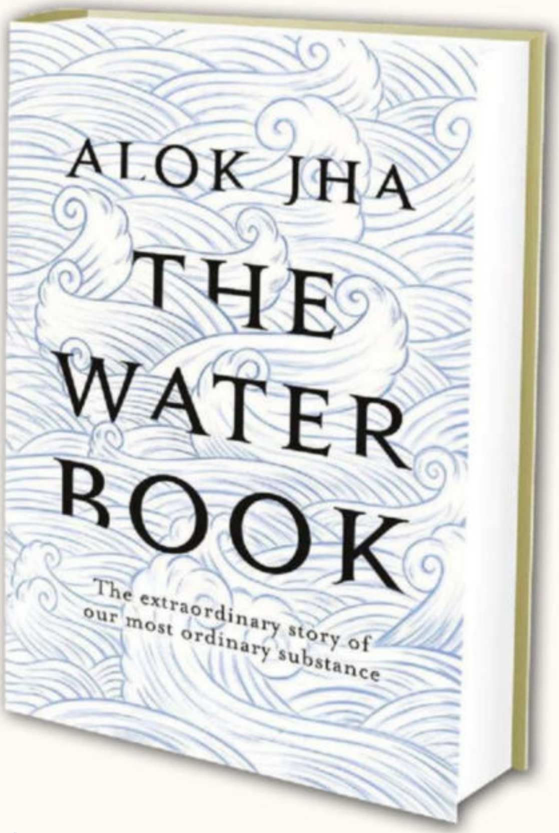

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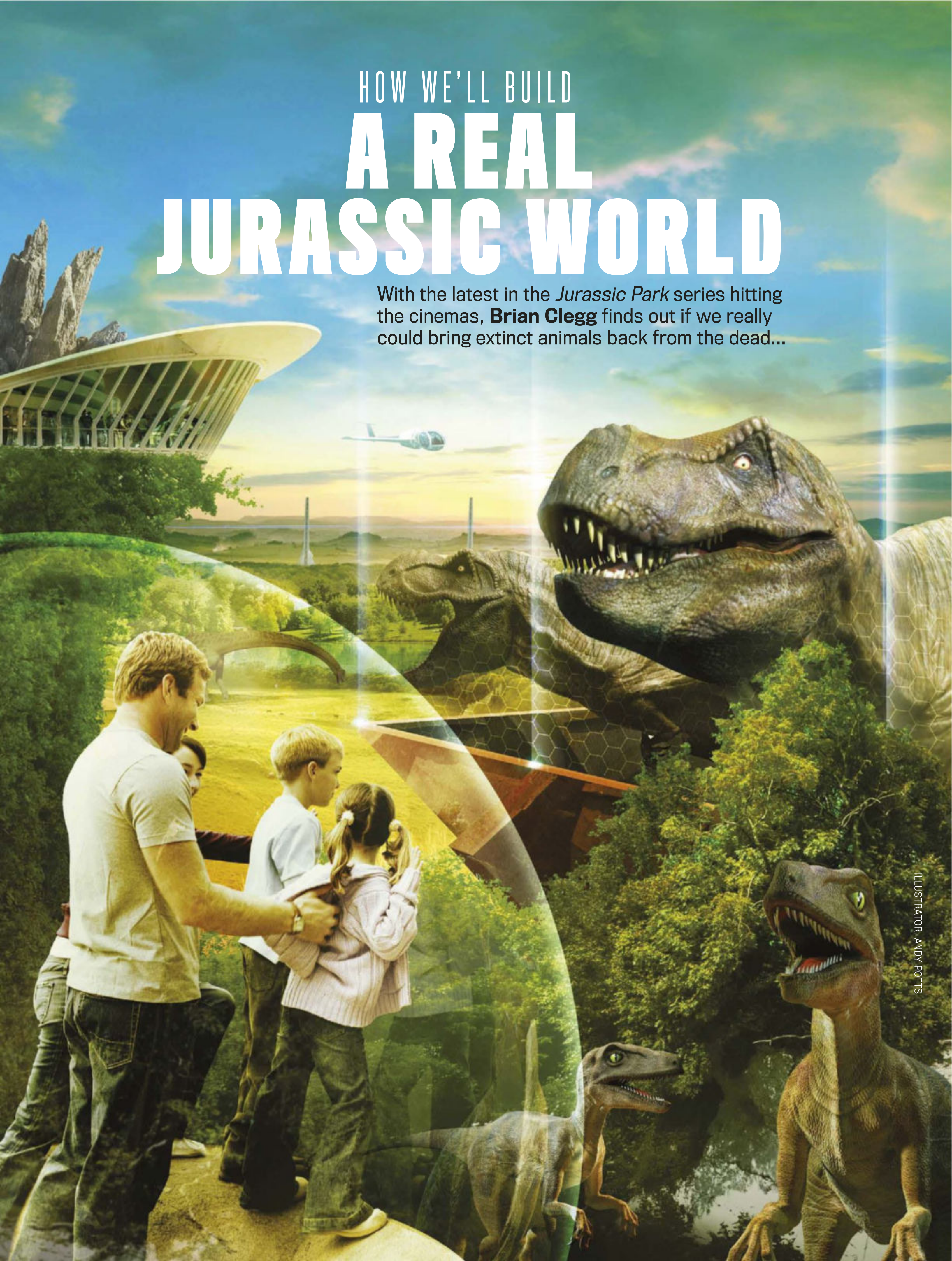


HOW WE'LL BUILD

A REAL JURASSIC WORLD

With the latest in the *Jurassic Park* series hitting the cinemas, **Brian Clegg** finds out if we really could bring extinct animals back from the dead...

ILLUSTRATOR: ANDY POTTS

HOW TO BRING BACK EXTINCT CREATURES

DINOSAURS HAVE CAPTURED our imaginations for decades, but recreating them is a formidable challenge. *Jurassic Park* author Michael Crichton suggested getting dino DNA from blood-sucking insects that had been preserved in amber. The good news is that amber (fossilised tree sap) does sometimes contain well-preserved insects. The bad news is we can't get useful DNA this way. The problem is the half-life of DNA molecules.

DNA is a complex, fragile substance. Over time it breaks down, becoming less and less readable. A team from the University of Copenhagen and Murdoch University in Perth found that in 521 years, half of a sample of DNA would be broken into useless fragments, after another 521 years another half and so on. This means that no part of a DNA sequence would be readable after 1.5 million years – far less than the 60 million plus required for resurrecting a dinosaur. Furthermore, a team at Manchester University that tried the insect-in-amber technique found that DNA degraded faster than normal in these conditions.

But there is hope for recently extinct mammals like the thylacine (Tasmanian tiger), which died out in the early 20th Century, or even 5,000-year-old mammoths, found preserved in permafrost. Not only can researchers find intact DNA to use, but there are also closer living relatives to act as host mothers. In fact, Prof Michael Archer of the University of New South Wales believes bringing back the thylacine is a distinct possibility.

"I'm hopeful, given the increasing frequency of major technological breakthroughs in synthetic biology, that it will be within the next 20 years," he says.

Some believe we will never clone a mammoth, despite there being two projects underway attempting just this. Other experts such as Dr Beth Shapiro, Associate Professor of Molecular Evolution at the University of California, Santa Cruz, are cautiously optimistic.

"It depends on what you are willing to call a mammoth," she explains. "If you are willing to accept an Asian elephant whose genome contains a very small amount of mammoth DNA – perhaps a few mammoth genes inserted in place of the elephant version of genes, so that an elephant is better able to survive in a cold place – then this could happen quite quickly. For mammoth de-extinction, the biggest challenge is probably not sequencing and assembling DNA or editing an elephant genome so that it

Human persecution wiped out the thylacine

Preserved bodies of thylacines still contain viable DNA

PHOTO: GETTY X2, KRIS KRUG/FLICKR, JENNIFER DOUDNA/UC BERKELEY ILLUSTRATOR: ANDY POTTS

Dr Beth Shapiro thinks that reverse engineering could help with de-extinction

looks more mammoth-like, but the later stages: implanting a developing embryo in a surrogate mom, having that pregnancy develop to term, rearing a newborn calf. These are challenges that not only do we not know how to solve, but that, ethically, remain questionable."

It would be remarkable if these extinct mammals were brought to life – but it isn't *Jurassic World*. Dinosaurs have a unique fascination and are the most attractive possibility for creation. And although it is not currently possible, what is proposed is 'dinosaur lite'. This would be a hybrid of an existing animal and a dinosaur.

Starting with the DNA of an animal descended from dinosaurs – a big bird, for instance – scientists would try to produce the characteristics we know, or suspect, dinosaurs had by genetic engineering. The result might be something that looked and acted like a *Tyrannosaurus rex*, but that would not truly be one.

"CRISPR, Clustered Regularly Interspersed Short Palindromic Repeats, are short gene-like sequences. They are often associated with a particular enzyme, Cas," explains palaeontologist Dr Henry Gee. "The CRISPR-Cas system – found naturally in bacteria – is a kind of immune system, allowing bacteria to resist invasion by viruses. In the past couple of years, it's become evident that the CRISPR-Cas system can be used for the precision editing of genetic material… in the science-fictional world of dinosaur genome reconstruction, it would be an essential part of the toolkit."

It might seem that an approximation to a dinosaur would be a pretty worthless animal, but Gee disagrees. "Given that almost everything we know about dinosaurs comes from bones, and everything else is a matter of guesswork anyway, who's to notice the difference?" he asks.

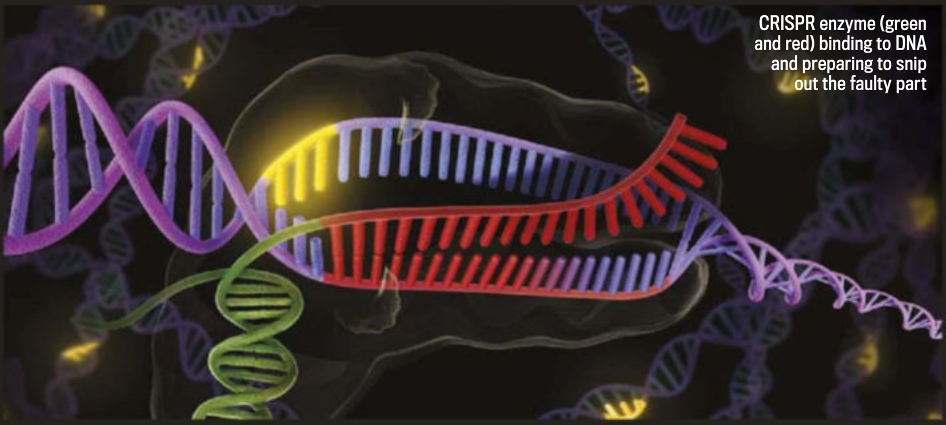
Dino hybrids would allow researchers to explore the realities of dinosaur life, which currently we can only guess at from the fragmentary remains we have.

But not every expert is hopeful of success. Michael Benton, Professor of Vertebrate Palaeontology at the University of Bristol, thinks that practicalities would overwhelm any attempt to manufacture a dinosaur.

"Reverse engineering DNA could be done now by snipping out bits and inserting bits, but who is to provide the pattern for DNA of any dinosaur? I can see no way we can provide even a faint guess at their genome," he says. "Why bother? And, if we could, surely we have more important purposes to which to put the technology – like engineering out disease or engineering in food productivity."

Predictably, Shapiro is more hopeful. "We now know the complete genome sequences of more than 50 species of birds, as well as alligators and crocodiles," she says. "Using these data, we can reconstruct, using a computer and models of how genomes change over time, what the most likely sequence of the common ancestor of birds was. We might then go into the genome sequence of a living bird and change it so that it looks like this common ancestor. For now, this is a thought experiment, of course."

While such a technique is not possible today, the rate of advances in gene technology mean it may be conceivable in 50 years. And, considering our love affair with dinosaurs, how could we resist?



CRISPR enzyme (green and red) binding to DNA and preparing to snip out the faulty part

The last mammoth population lived on Wrangel Island, 140km off the coast of northeast Siberia, and died out around 4,000 years ago

HOW TO REAR DINOSAURS TO MATURITY

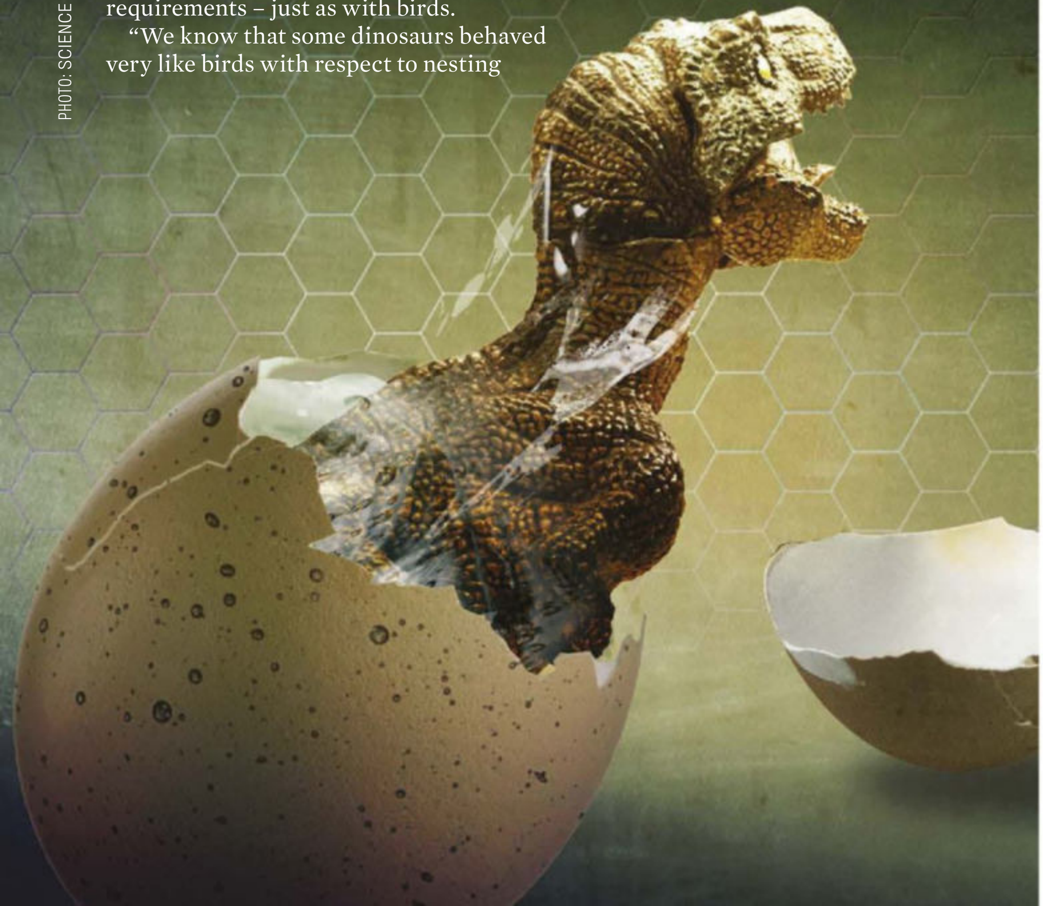
EVEN WITH DINOSAUR DNA, the route to a fully-grown animal is complex. “To work properly, DNA has to be packaged,” explains palaeontologist Dr Henry Gee. “Many parts of DNA are coiled around protein complexes called histones. The degree to which DNA is wrapped around histones has a bearing on which genes are turned on during development and when.

Gee adds that much of DNA is modified chemically, as part of a pattern called the epigenome. This is also vital in development. “The most important thing, however, is the early maternal environment. The earliest stages in the development of an embryo depend on chemical factors left in the egg by the mother. Even having the right factors in the right places within the egg is important,” explains Gee. “As we don’t have fresh dinosaur eggs to work with, we’d have to use crocodile or bird eggs. Scientists know an awful lot about chicken eggs, so perhaps they’d start with those.”

Luckily, not all dinosaurs were on the scale of *Diplodocus* – there were plenty of chicken-sized dinosaurs that we could experiment with before jumping straight to the big boys. When it comes to rearing, we would need to be aware of species requirements – just as with birds.

Not all dinosaur eggs were as big as this

“We know that some dinosaurs behaved very like birds with respect to nesting and incubation,” says Gee. “We also know that reproductively active female dinosaurs underwent secondary remodelling of their bones, associated with providing calcium for the eggshells and embryos. So, in some cases at least, birds and dinosaurs behaved very similarly. But dinosaurs were very diverse, and it is possible that they had a range of reproductive habits, from full-on parental care, to laying eggs in a nest or mound and forgetting all about them.”



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HOW TO MANAGE THEM

THE OWNERS OF a dinosaur reserve would need to keep their animals safe and happy, while giving visitors a chance to see them as close-up as possible. The European Association of Zoos and Aquaria (EAZA) produces a detailed file on the management of each major species called an EEP (European Endangered Species Programme), which would need to be extended to include dinosaurs.

The difficulties of handling large dinosaurs are likely to be surprisingly similar to those faced when looking after large mammals – a fully-grown male African elephant can weigh up to seven tonnes, a similar weight to a *T. rex*. Although a large, grazing sauropod like a *Diplodocus* could weigh up to three times as much, they would be far slower. They would therefore provide less of an issue for any barrier than a high-speed predator. In practice, it’s likely that the dinosaurs could be kept in place by using traditional concrete and rock barriers.

Bob Lawrence, Head of Wildlife Development at West Midland Safari Park, points out that one vital aspect of keeping animals secure is understanding the social grouping of the particular species. For example, some tolerate a male hierarchy, but others only allow one mature male in a group. The latter

For continuity, *Jurassic World's* producers stuck with scaly dinosaurs like those above, but the fossil record suggests *Velociraptors* and some other dinosaurs had feathers (left)

scenario would result in battles where the loser would attempt to flee and could try to charge out of the enclosure, putting the containment under stress. With our limited understanding of dinosaur social groupings, there would be an initial need for an environment where security was paramount to avoid escapes.

Elephants are often confined using electric fences, but Lawrence points out that not only are these potentially inhumane, but more intelligent species can find ways to disrupt them. Elephants have been known to short them out using tree branches and there is always the possibility of technical failure. Steel barriers or high walls would need to be capable of withstanding the impact of charging dinosaurs. When housing elephants, about 2.5m is the recommended minimum height for a barrier, but in the case of taller dinos, this would have to be increased appropriately.

For smaller predators like *Velociraptors*, Lawrence recommends the kind of fencing used for wolves, which typically involves a 45-degree inward overhang. This is essential when the animals can be good jumpers.

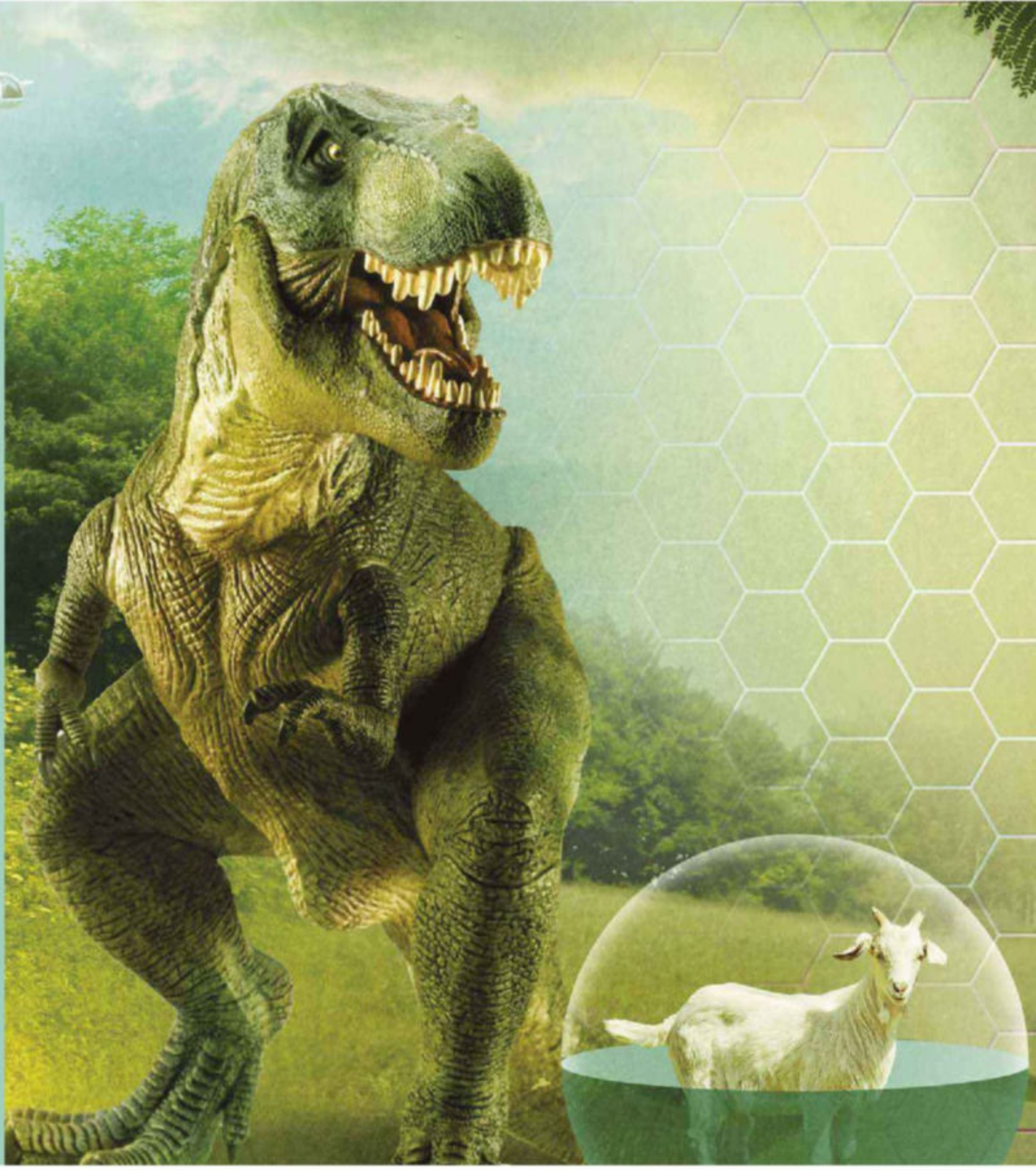
Lawrence recommends siting a dinosaur park in an old quarry, such as the disused chalk pits in Kent. These can have sides over 30 metres deep, keeping the animals safe from escape. Such a location can also make a very attractive visitor site, as the Eden Project in Cornwall has proved. It would also be much more secure than using an island to confine species when we don't know how well they'd cope with water. "We were caught out once when we didn't realise that wallabies could swim. We used an island to confine them and within 24 hours they all swam off," Lawrence explains.

According to Bob Lawrence, we must understand social groupings to keep animals safe and secure

For smaller dinosaurs, existing bird enclosures would likely prove fine.

"One might have greater success with some of the smaller, feathered dinosaurs, no bigger than crows or pigeons, which could be kept in a large aviary," says Gee.

For a thylacine, the issues would be similar to those in breeding any large animal. "The same issues would need to be addressed, including optimising genetic diversity and acclimatisation



FIVE FREEDOMS

Zookeepers refer to five freedoms of animals, which would inevitably be extended to dinosaurs. These are:

1. Freedom from hunger and thirst
Adequate, well-balanced and timed nutrition must be provided.

2. Freedom from discomfort
A suitable environment with shelter and appropriate materials allows animals to live as closely as possible to a natural environment.

3. Freedom from pain, injury and disease
Animals should not be put at risk by the enclosure and should have good access to veterinary medicine.

4. Freedom from fear and distress
These can be avoided by providing correct grouping and sex ratios, and including an appropriate mix of species. There should be a lack of unnecessary confinement and places to escape from view.

5. Freedom to behave normally
In old-fashioned zoo environments, animals would pace unnaturally. Instead, they should have somewhere to express their natural behaviour as closely as possible.

PHOTO: PRESS ASSOCIATION, JOHN D/CATHERINE T/MACARTHUR FOUNDATION ILLUSTRATOR: ANDY POTTS

to the attributes of potential release habitats," says Archer. "For some animals and plants, a parallel conservation strategy might involve enabling suitable species to become human companions. If this had been legal when thylacines were being kept as pets in Tasmania, it's depressingly clear that the thylacine would not be extinct today. There are lessons to be learned from this tragedy, based on the erroneous presumption that wildlife is always safest in the wild."

There is always going to be compromise, but good zoos and wildlife parks will have the animals' welfare at their heart. The trouble with dinosaurs is that so much would initially be a matter of guesswork.

Take the *T. rex*. For years this dinosaur with immensely powerful jaws was considered a straightforward predator. Yet some palaeontologists suggest that, like a hyena, it was almost entirely a scavenger and primarily lived off the kills of others. There is evidence to support both theories, which is typical of the uncertainty we face.

Equally, there is some evidence that *T. rex* indulged in cannibalism. After years of hard work, it would hardly be great news if one specimen ate the rest. Similarly, although it has been suggested that dinosaurs were less susceptible to disease than mammals, this is based on inference from the fossil record, which is patchy in the extreme.

Computer modelling suggests that an adult *T. rex* could bite with a force of over five tonnes

With very large animals, there is also the problem of getting enough food into the enclosure at a time. A *T. rex* would probably need 40,000 calories a day, equivalent to eating a large goat. There's no reason why it couldn't cope with modern meat, though if it proved to be primarily a scavenger it would be more likely to be fed with, say, a cow carcass on a less frequent basis. Any sensible *T. rex* facility would have a failsafe mechanism for delivering food without having to risk physically entering the enclosure.

A large herbivore like *Diplodocus* probably had a diet of ferns and soft leaves – there would be considerably more concern about finding appropriate diets (think, for example, how fussy a panda is in requiring bamboo shoots). But whatever the exact plant life involved, an animal with this bulk would need large quantities of vegetation – perhaps half a tonne per day. In this case, the supply might be challenging, but at least the enclosure can be entered with less risk.

Currently, we know so little for sure. This is why, even if they weren't perfect, the idea of creating dinosaur hybrids could help palaeontologists get a better picture of Jurassic and Cretaceous life.

WHO WOULD RUN THE PARK?

While none of these individuals is involved in creating a dinosaur attraction, they're exactly the kind of people such a venture would need...

THE ANCIENT DNA EXPERT

DR BETH SHAPIRO

Recreating dinosaurs would mean finding out as much as we could about their DNA and reverse engineering what we couldn't find. An expert in ancient DNA is an essential cast member, and Shapiro already has a project working on a form of reverse engineering.

THE DE-EXTINCTION EXPERT

PROF MICHAEL ARCHER

Archer and a small number of individuals are looking at the practicalities of producing a living specimen of an extinct creature. The work currently focuses on recently extinct mammals, but for the park that would have to be extended much further.

THE PALAEONTOLOGIST

PROF MICHAEL BENTON

We can't get anywhere without an expert in dinosaurs. These scientists can help us discover remnants and will increase our understanding as much as possible. They can teach us about the lifecycles of the animals to give us the best chance of successfully rearing them.

THE BACKER

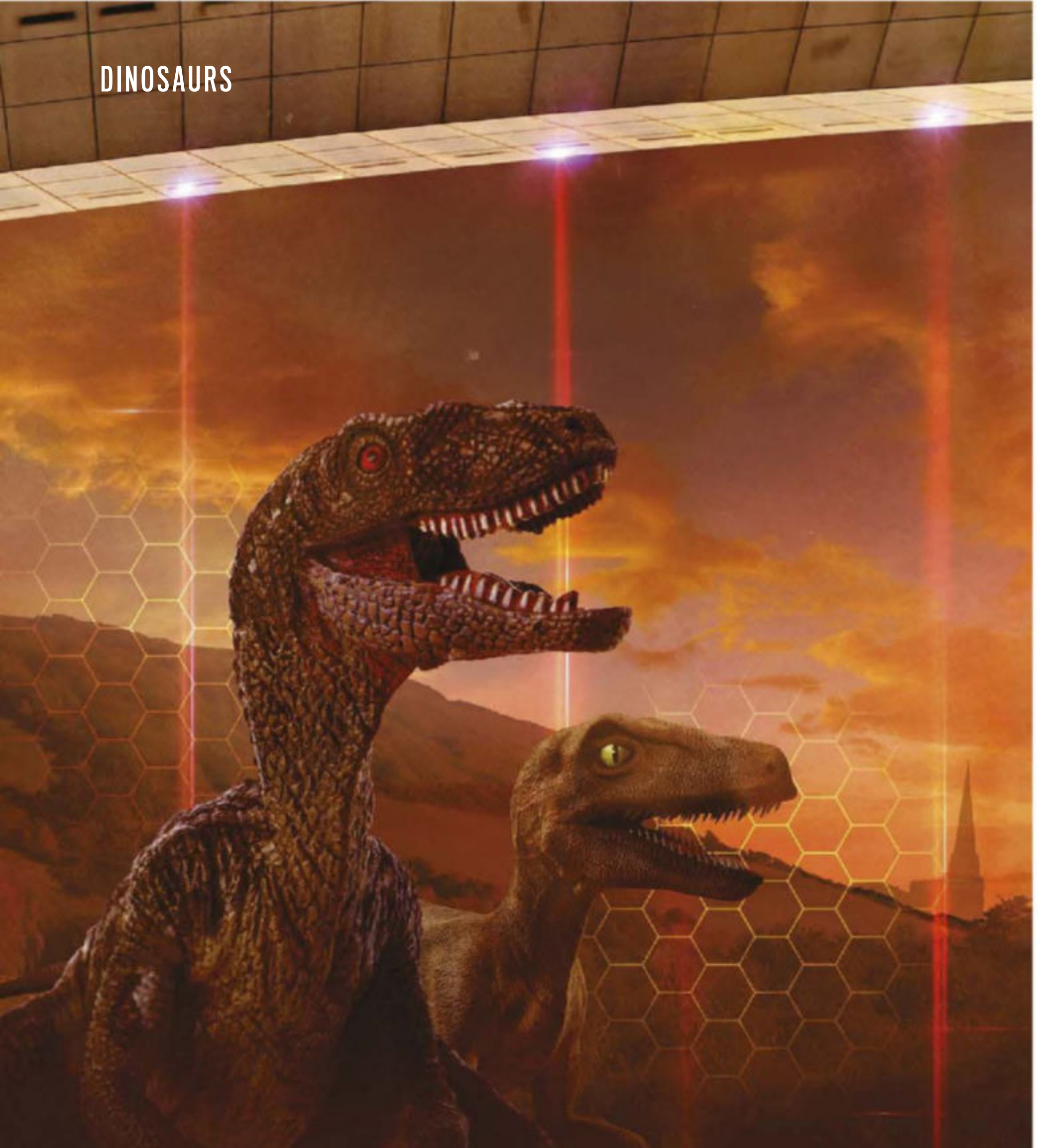
CLIVE PALMER

This eccentric Australian mining billionaire is exactly the kind of backer that would be essential to get an ambitious project like this off the ground, as it would require a huge amount of funding. According to the Australian press, Mr Palmer has already expressed an interest in cloning dinosaurs.

THE SHOWMAN

SIR RICHARD BRANSON

There is no doubt that the Virgin owner is an ultimate showman and he already owns a private game reserve, Ulusaba in South Africa, adjoining the Kruger National Park. Sir Richard's ebullient enthusiasm and media access make him an ideal candidate for launching a dinosaur park.



WHERE TO PUT THE PARK AND HOW TO ENGINEER A HABITAT

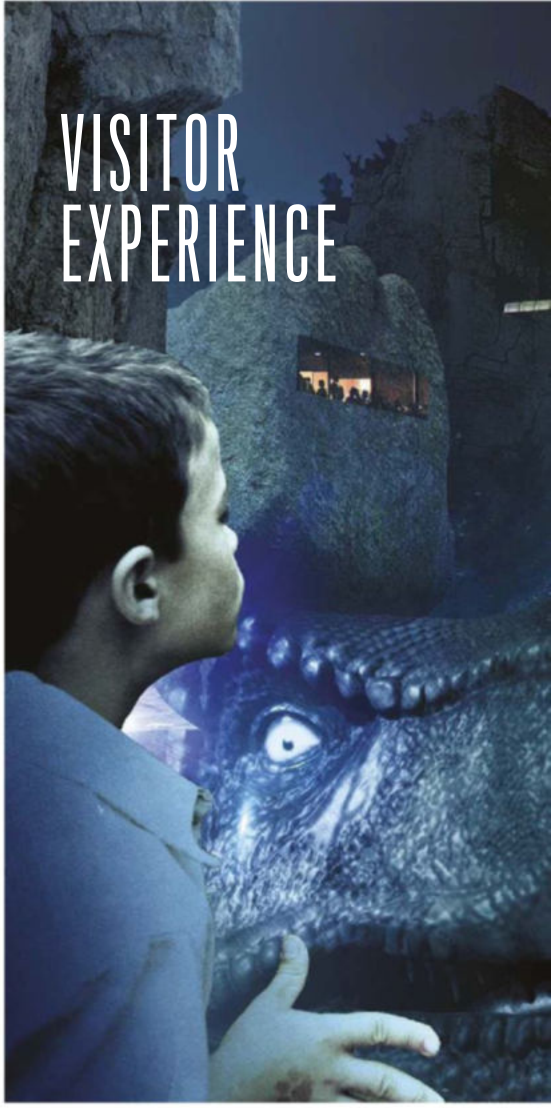
WE TEND TO lump together dinosaurs as a single group of animals – but they lived over a huge time period from the Jurassic (200-145 million years ago) when massive herbivores like *Diplodocus* were common, through to the late Cretaceous (100-66 million years ago), when the likes of *T. rex* and *Velociraptor* thrived. Not surprisingly, the habitats varied. But generally the need would be for a warm, humid environment with plenty of coniferous trees and fern plantations.

However, it isn't always essential to match a habitat to an animal. With suitable winter protection, African animals can survive comfortably in British safari parks. And it may be that dinosaurs would be equally adaptable, although this is something that would require experiments with living animals to determine. With this in mind, the first park would require highly controlled and large-scale environments. As such, it wouldn't really matter where in the world the park was situated. The driving factor would more likely be the source of funding.

The key to the adaptability of the animals would be whether they resembled warm-blooded birds, or cold-blooded crocodiles. A fully warm-blooded organism can cope with much wider ranges of climate, whereas cold-blooded animals require a more controlled temperature range to thrive. Although we have moved away from the idea that dinosaurs were cold-blooded, we still don't know for sure whether something like a *T. rex* had a full-scale warm-blooded metabolism or something in between the two, leaving it more susceptible to the cold. The only way we can find out for definite is by experiment.

Modern birds are descended from a group of dinos called theropods

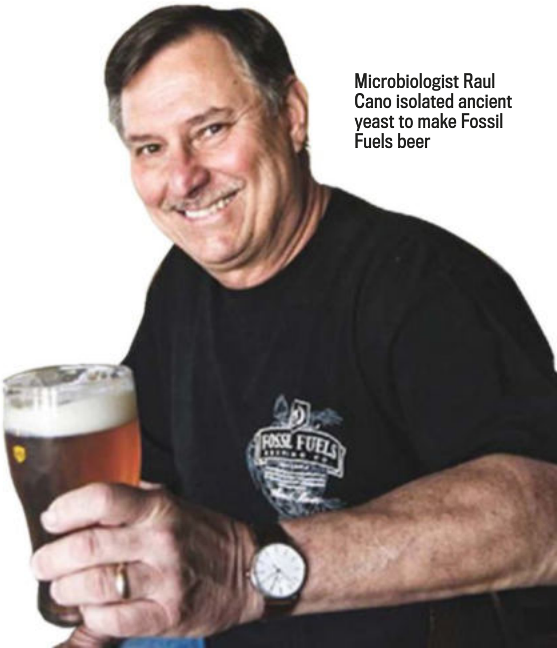
PHOTO: JAYSON MELLOW, NBC UNIVERSAL ILLUSTRATOR: ANDY POTTS



VISITOR EXPERIENCE

DINOSAURS WOULD BE so valuable that the visitor experience would come second to security. Good walls, designed to look like natural structures, with viewing points and ports would give the best combination of safety and access. In a future Eden Project-style environment, there could be virtual robotic tours of the enclosures and the ability to fly over the the top in a totally transparent vehicle.

We know already from dinosaur exhibitions that there will be plenty of



Microbiologist Raul Cano isolated ancient yeast to make Fossil Fuels beer

spinoffs. It's unlikely that the restaurant would serve actual mammoth or dinosaur burgers, but it would be possible to use the same technology that produced a £200,000 lab-grown burger to grow mammoth and dinosaur meat. Bear in mind that in less than two years, the price of making a lab burger has dropped to under £10. To accompany their meal, visitors might like a glass of the Fossil Fuels Brewing Company's beer, claimed to be made using a yeast strain dating back 45 million years.

No doubt dinosaur toys making realistic sounds would be popular – but as yet, we have little idea of the noises that dinosaurs made. There has been speculation that strange bony head crests on some duck-billed dinosaurs were used to create resonant cries, but most dinosaur noises featured in movies and documentaries are simply reused from existing animals.

Palaeontologist Phil Senter has even suggested that dinosaurs may not have had cries at all. This is because their two living descendants, the birds and crocodilians, have totally different sound-making mechanisms from each other, suggesting their common ancestor may have had neither. But after the noise of the *Velociraptor* claws on the floor in *Jurassic Park* gave us nightmares, we'll be thinking twice about a dino attraction… ■

We could safely explore a dinosaur attraction in transparent pods, like the ones featured in *Jurassic World*

BRIAN CLEGG is a science writer whose most recent book is *Science For Life*

Find out more

To find out more about dinosaurs from BBC iWonder, visit **bbc.co.uk/guides/zyrx34j**

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WHEN THE WELL

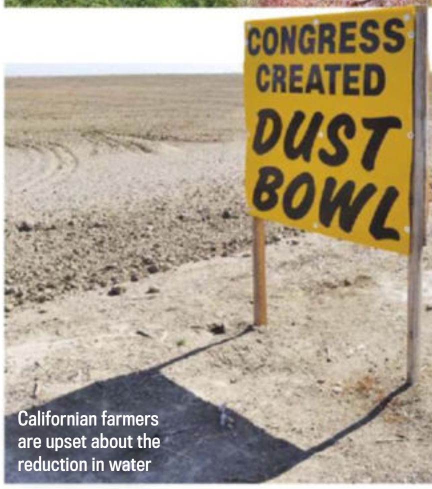
RUNS DRY

After a fourth consecutive year of drought, California's reservoirs are running dry. **Hayley Birch** looks at the technology that could help solve the crisis, and put an end to drought around the world

THE WEBSITE OF LawnLift proclaims that, "It's like a facelift for your lawn!" The US company offers a quick fix for crispy-looking Californian lawns by painting them green. Since the onset of drought in the state, spray painting lawns has become big business. More than three years on, with the drought showing no sign of ending, the Californian water board has adopted emergency regulations that make watering your garden more than twice a week a punishable offence. At the beginning of April, state governor Jerry Brown announced restrictions that will force water suppliers to reduce their output by a quarter, by February 2016.

It's not just the lawns that are parched. Levels at lakes and reservoirs have dropped to historic lows and farmers are leaving fields unplanted because there isn't enough water to irrigate their crops. Like anyone who lives in California, Brian Luenow, who works in water pollution monitoring in San Francisco and runs a website covering water issues called HydrateLife, sees a lot of the impact. "Along Highway 5, the big highway that runs the length of California, you see empty fields, you see dead trees. You see a lot of signs put up by farmers, because some of them aren't getting water from the government this year, so there are a lot of people upset by that."

Grass painting is now big business in California



Californian farmers are upset about the reduction in water

WHERE'S THE WATER?

Water scarcity is a problem that affects countries in every part of the world, either because they experience periods of extremely dry weather, or because populations are increasing rapidly, or because the water isn't distributed properly – or all of the above. For decades, the amount of water we use globally has been growing faster than the population, meaning that within 10 years we could be living in a world where two-thirds of people face 'water stress'. This is a situation where the demand for water is greater than the supply. African countries are some of the most water stressed, but even some European countries and US states are facing serious challenges in supplying enough. The world's well is running dry.

In arid countries like Israel, which gets practically no rain between May and September, conserving water is a way of life. In contrast, Californians don't think

PHOTO: ISTOCK, GETTY, ALAMY

about it as much. “They’re used to just turning on the taps and having water,” says Luenow. Over time, education might be able to change the West’s attitude to water, but that will only go so far. Luckily, solutions to our global water shortages could be on the horizon.

> **“The public need to be made more aware of what’s happening with water”**
>
> Brian Luenow, founder of the HydrateLife website

ACROSS THE DIVIDE

Israel gets 40 per cent of its water from the sea through desalination, which involves removing salt from seawater. This is a solution to which the Golden State is now turning. One of the most widely used desalination technologies – the reverse osmosis membrane – was invented back in the 1950s. The trouble is, the process uses a lot of energy. But today, researchers in Cambridge, Massachusetts think they may have found a way to make it meet the demands of the modern world.

Reverse osmosis uses high pressure to force seawater through a membrane. The salt can’t get through and is left behind. At the Massachussetts Institute of Technology, Dr Rohit Karnik’s team has been working on a reverse osmosis membrane made from graphene, a carbon ‘wonder’ material that’s atomically thin. In a study published last year, they showed they could make trillions of nano-sized pores in their graphene by firing gallium atoms at it and then using chemicals to open up the pores to just the right size to let water molecules through.

Compared to a traditional reverse osmosis membrane, a graphene membrane would create less resistance to the flow of water, working like a sieve to rapidly filter out salt. This kind of precision filtering would demand far less energy to clean salt from seawater. Plus the filter itself would be stronger and longer-lasting, according to Karnik.

Across California, desalination projects that were built and then deserted or downscaled after previous droughts are

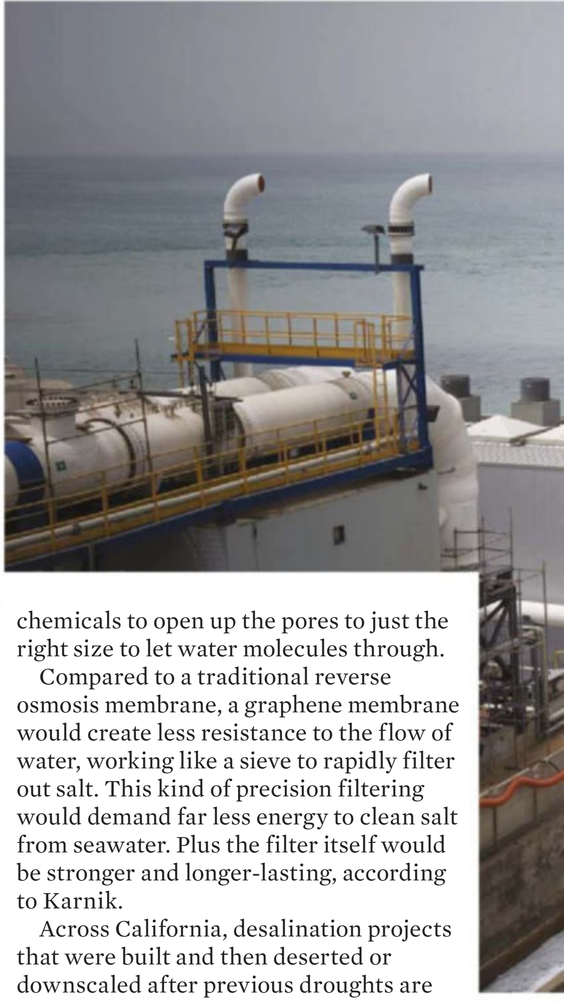


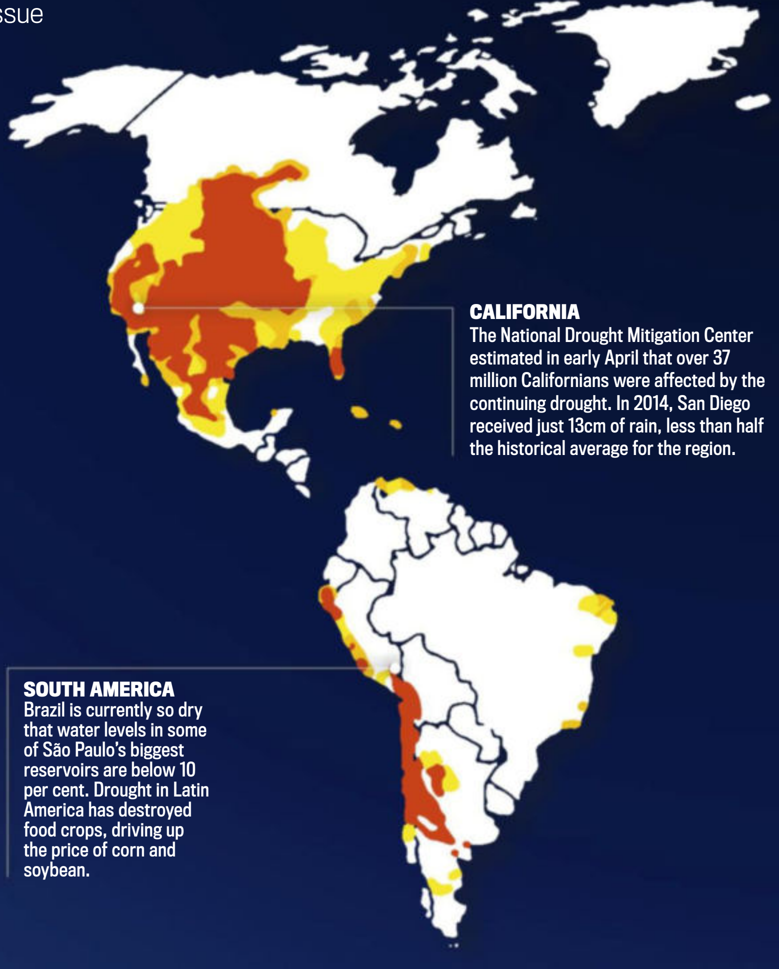
PHOTO: PRESS ASSOCIATION

WATER STRESS

The shortage of water is not limited to a handful of countries – it’s a worldwide issue

70% of the world’s accessible freshwater is sucked up by agriculture

783 million people do not have access to clean water



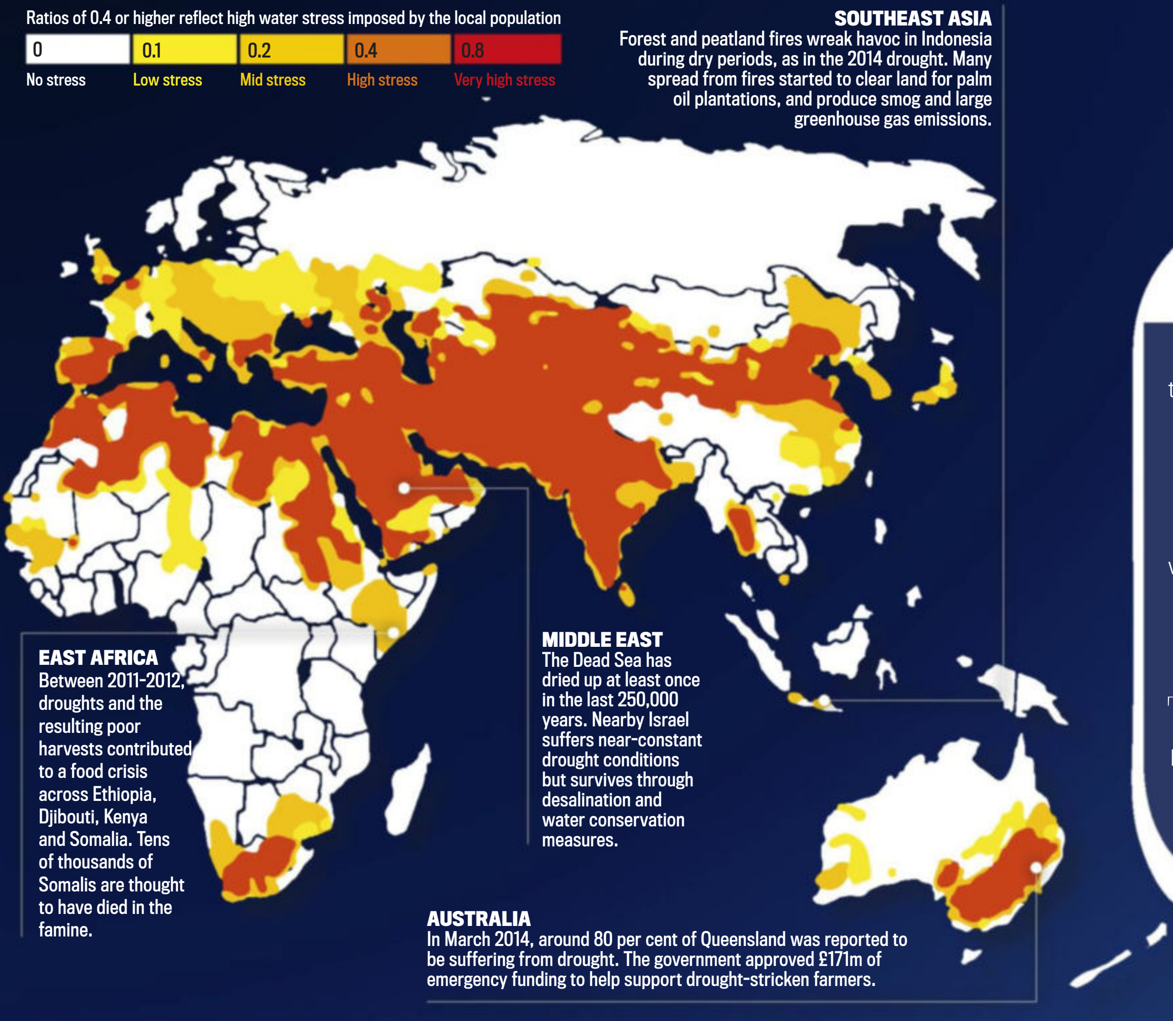
CALIFORNIA
The National Drought Mitigation Center estimated in early April that over 37 million Californians were affected by the continuing drought. In 2014, San Diego received just 13cm of rain, less than half the historical average for the region.

SOUTH AMERICA
Brazil is currently so dry that water levels in some of São Paulo’s biggest reservoirs are below 10 per cent. Drought in Latin America has destroyed food crops, driving up the price of corn and soybean.

Israel's Hadera desalination plant provides clean water for one million of the country's inhabitants

being revitalised, although they won't use graphene filters just yet. Higher performance membranes could eventually mean more efficient desalination, but what about the cost of these filters? Graphene has a reputation for being expensive to make, but Karnik thinks the cost of production will come down as it gets adopted for applications such as flexible electronics. "Some companies are already making it roll-to-roll," he notes.

On the other side of the Pacific, city state Singapore is known for its innovative water practices. It uses membrane filtering technology to get as much as a quarter of its water from desalination. But it also uses reverse osmosis for another reason: to turn waste water into drinking water at its NEWater purification plants. In the US, this reclamation process is often branded 'toilet-to-tap' and it's a tricky subject. Luenow says the government needs to make a bigger effort to teach people about these kinds of new technologies and how desperately they're needed. "There have been a lot of studies on it and the consensus is that what's coming out at the outlet is perfectly fine to


Ratios of 0.4 or higher reflect high water stress imposed by the local population
0
0.1
0.2
0.4
0.8
No stress
Low stress
Mid stress
High stress
Very high stress

SOUTHEAST ASIA
Forest and peatland fires wreak havoc in Indonesia during dry periods, as in the 2014 drought. Many spread from fires started to clear land for palm oil plantations, and produce smog and large greenhouse gas emissions.

EAST AFRICA
Between 2011-2012, droughts and the resulting poor harvests contributed to a food crisis across Ethiopia, Djibouti, Kenya and Somalia. Tens of thousands of Somalis are thought to have died in the famine.

MIDDLE EAST
The Dead Sea has dried up at least once in the last 250,000 years. Nearby Israel suffers near-constant drought conditions but survives through desalination and water conservation measures.

AUSTRALIA
In March 2014, around 80 per cent of Queensland was reported to be suffering from drought. The government approved £171m of emergency funding to help support drought-stricken farmers.

By 2025, **two-thirds** of the world's population could face water shortages

1976

was the year the UK's worst drought took place. It led to a Drought Bill being passed by Parliament

Two million

people die annually due to a lack of safe drinking water drink. I think the public need to be made more aware of the bigger picture of what's happening with water, because if people don't realise how bad this drought is, they're not really going to see the need for this kind of thing."

Using our waste and the seas to provide clean water could help Californians maintain their way of life during the droughts, but ultimately it won't be much help to those that need relief most. Developing countries, particularly those that are landlocked, will have to look for more radical solutions.

DROUGHT DEFENCE

One answer might be genetically modified crops that cope better in dry conditions. For desperate farmers, planting crops that are specially engineered to resist drought could be one way to prevent fields from falling fallow. Plant scientist Sean Cutler is working on switching on genetically engineered drought tolerance using chemicals already available to farmers. Based at the University of California, Riverside, Cutler's own institution has an action plan for water conservation and there have been local quarrels over sprinkler usage, with one city councillor complaining he'd have to move house if restrictions wouldn't allow him to water all his shrubs.

The approach Cutler's team described in *Nature* earlier this year could be applied to many different crops, but they tested it in a model species called *Arabidopsis*, which is related to cabbages. They'd already tracked down the right receptor – a molecular switch in the plant that triggers water storage, including by closing pores in the leaves that let water vapour escape. In the new study, they edited the plant DNA that encoded that receptor so it could be activated by a fungicide usually used for crop protection. "It's the first time anyone's ever taken a plant and made it so that an agrochemical can turn on a pathway that it wasn't designed to regulate," says Cutler. "There are other receptors in the plant that could be activated chemically and there's no reason why you couldn't apply the strategy that we outline to those." The idea is that, eventually, it might be possible to spray a field of crops with one chemical and have it switch on a whole raft of different drought defence mechanisms.

In the US, as in Europe, there is still some resistance to genetically modified organisms (GMOs). But as Cutler explains, unless the crops have new genes added to them, they are not considered to be genetically modified in the US. "So there are probably [genetic] strategies we could exploit without invoking the GMO issue," he says.

Sean Cutler believes a particular fungicide could 'switch on' a plant's drought defence mechanisms

HOW SPIDER SILK COLLECTS WATER

Why do spider webs sparkle like diamonds on a dewy morning? It's all down to their intriguing structure...

MANY WATER-HOARDING materials exist in nature, such as the leaves of certain plants and the backs of desert beetles. Incredibly, spider silk also has a structure that is perfectly adapted to water collection. In 2010, a team of Chinese researchers published a paper in the journal *Nature* revealing important details of this structure. The scientists showed that when spider silk gets wet, rough-textured bumps start to form along the otherwise smooth fibre of the silk. The difference in the texture of the silk creates differences in pressure and energy that drive water towards the bumps, enhancing the silk's water-collecting ability. This is why we see water clinging to a spider's web in distinct droplets, with the bumps – or what the scientists called 'spindle knots' – acting as collection sites. The challenge now is to create cheap, bio-inspired materials that mimic the structure of natural spider silk to harvest moisture from fog in dry regions. The materials, which are designed by Prof Yongmei Zheng and her team at Beihang University, are made by dip-coating a smooth artificial fibre in a polymer fluid that breaks up and dries to form the bumps that are so crucial to the structure.

Tiny bumps on spider silk help capture drops of dew

PHOTO: UCR STRATEGIC COMMUNICATIONS, NEIL HALL X3, FLPA

South America has seen a great deal of success with collecting fog using mesh-like nets, such as these in the Atacama Desert

Drought-tolerant crops are a solution that could be employed in most places in the world, particularly in inland regions where desalination isn't such a straightforward option for a water supply. Some African nations using more traditional crop breeding approaches have already been helping growers to make the best of the dry conditions. In Chad, for example, subsistence farmers started sowing drought-tolerant sorghum seeds in the 1990s, leading to increases in yields of the grain by up to half.

WATER FROM THIN AIR

Reducing the amount of water you use is one thing, but coming up with new water sources in places where there is very little is quite another. One quirky approach being tested in communities all over the world is fog collection. Everywhere from Chile to Oman, researchers and local people have been stringing up nets to soak up water from thin air.

These nets are reminiscent of giant spider webs capturing droplets of dew. In fact, at Beihang University in Beijing, China, Prof Yongmei Zheng and her team are taking inspiration from spider webs to make better fog-collecting materials. After finding that water collects on tiny bumps in spider silk, they mimicked the bumpy structure with artificial, nylon-like materials and worked out a way to spin them into long threads. "Many fog-catching projects around the world seem to use the same materials that have been used for a long time," says Zheng. "The bioinspired fibres have a better ability to collect water than the normal fibres." She says they are developing experiments to test the fibres outside the lab and hope to set up projects in foggy regions elsewhere in the world.

> **"Bioinspired fibres have a better ability to collect water than the normal fibres"**
>
> Prof Yongmei Zheng, Beihang University

Back in California, Luenow is considering building a fog-catcher at home, although he hasn't got round to it just yet. Perhaps artificial cobwebs won't solve all of California's water problems, but then it's unlikely any single solution will. In one Guatemalan project utilising 30 fog-catchers, local families in Tojquia collected a total of around 6,000 litres a day. That's enough for about 3.5 Californians, based on 2011 figures, though at that point more than half of daily water consumption related to outdoor uses such as landscaped gardens.

Luenow worries that people still aren't waking up to the issue of water scarcity, even after years of drought. "Most people have never even thought about the fact that water could become so scarce," he says. He suggests everyone has to take a little bit more responsibility – from the politicians, to farmers and bottled water companies pumping water out of the ground, and residents who care too much about having a pretty garden and not enough about having sufficient water to drink. We need to work together before Earth is no longer the Blue Planet... ■

HAYLEY BIRCH is a science writer and author of *50 Chemistry Ideas You Really Need to Know*, due out in 2015

Find out more

BBC WORLD SERVICE

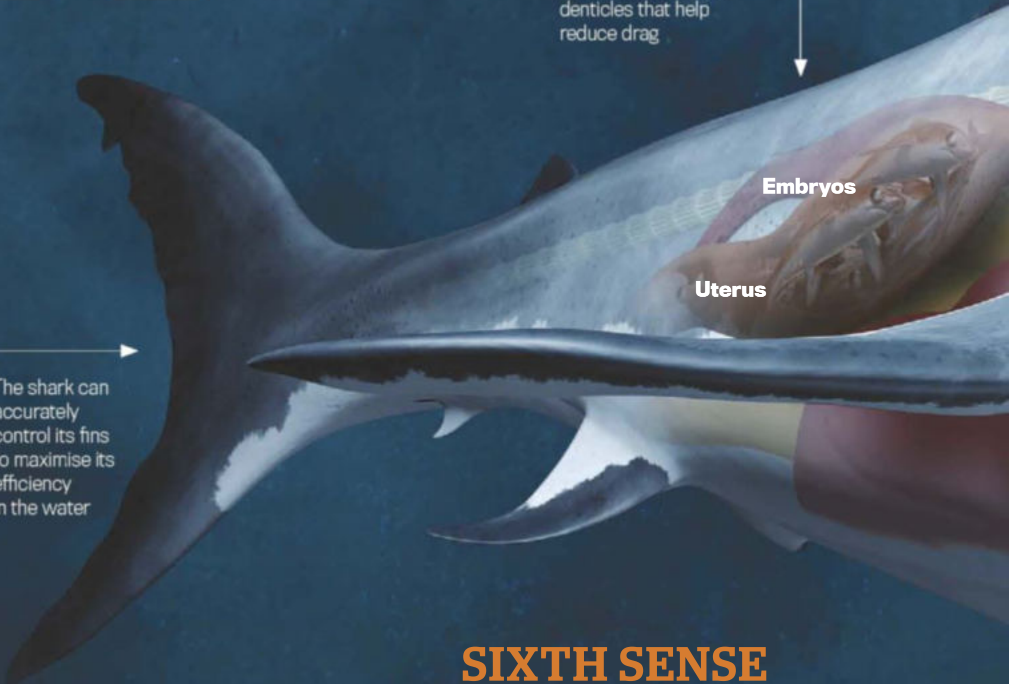
To listen to a *Science In Action* programme about the Desolenator desalination device, visit **bbc.co.uk/programmes/p02dgdhf**

YOU'RE GONNA NEED A BIGGER BOAT

It's 40 years since *Jaws* warned us not to go in the water. It's about time we got our teeth into the science behind this stunning predator, says **Ken Wu**

SPEED

THE ANIMAL CRUISES at 8km/h (5mph), but can attain a top speed of 50km/h (31mph) for short bursts when chasing prey. It has a light, cartilaginous skeleton instead of bone, which makes it flexible and capable of executing rapid turns. The great white belongs to a group called the laminid sharks; unlike most other fish, these can keep their bodies warmer than the surrounding water, allowing them to swim faster and for longer.



Shark skin is covered with tiny, tooth-like scales called dermal denticles that help reduce drag

The shark can accurately control its fins to maximise its efficiency in the water

SIZE AND WEIGHT

THE AVERAGE LENGTH of adult great whites is between 3.7 and 4.9m, yet some truly enormous specimens have been reported. An example is one that was caught near Cojima, Cuba in 1945 measuring 6.4m. This shark allegedly tipped the scales at 3.3 tonnes, whereas adults normally weigh around 1.9 tonnes. However, the size and weight of this huge shark cannot be confirmed as accurate measurements were not taken at the time.

A great white is a similar length to a Ford Focus

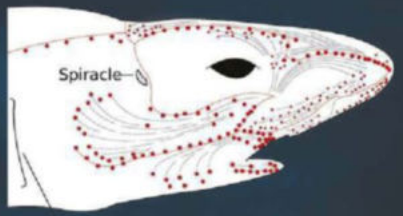
ILLUSTRATOR: MAGIC TORCH

REPRODUCTION

REPRODUCTIVE HABITS ARE mysterious in the great white, and no female has ever been seen giving birth. The mother develops the eggs in her **uterus**, which then hatch out inside her. The **embryos** get nutrition from a yolk sac and may even eat unfertilised eggs. Scientists think that the pups are born after 14-18 months gestation and measure between 1.1m and 1.65m. We cannot be certain when they reach sexual maturity, but it may be up to 26 years for males and 33 years for females. Youngsters predominantly prey on fish and then later expand their palate to include marine mammals.

SIXTH SENSE

LIKE ALL SHARKS, the great white has a sixth sense that humans lack: electroreception. Special pores around the snout, eyes and lower jaw contain electrically conductive cells called the ampullae of Lorenzini, allowing the shark to detect tiny amounts of electrical activity generated by the muscle cells of potential prey. These nifty pores may even help the sharks to navigate using the Earth's magnetic field.



The ampullae of Lorenzini detect electrical activity

LIVER

THE SHARK'S LARGEST organ is the **liver** making up 28 per cent of its body weight. It contains large stores of fat and oils, which provide it with buoyancy since it lacks the gas-filled swim bladder that many other fish have. The liver also fuels its long migrations that can cover over 4,000km (2,500 miles).

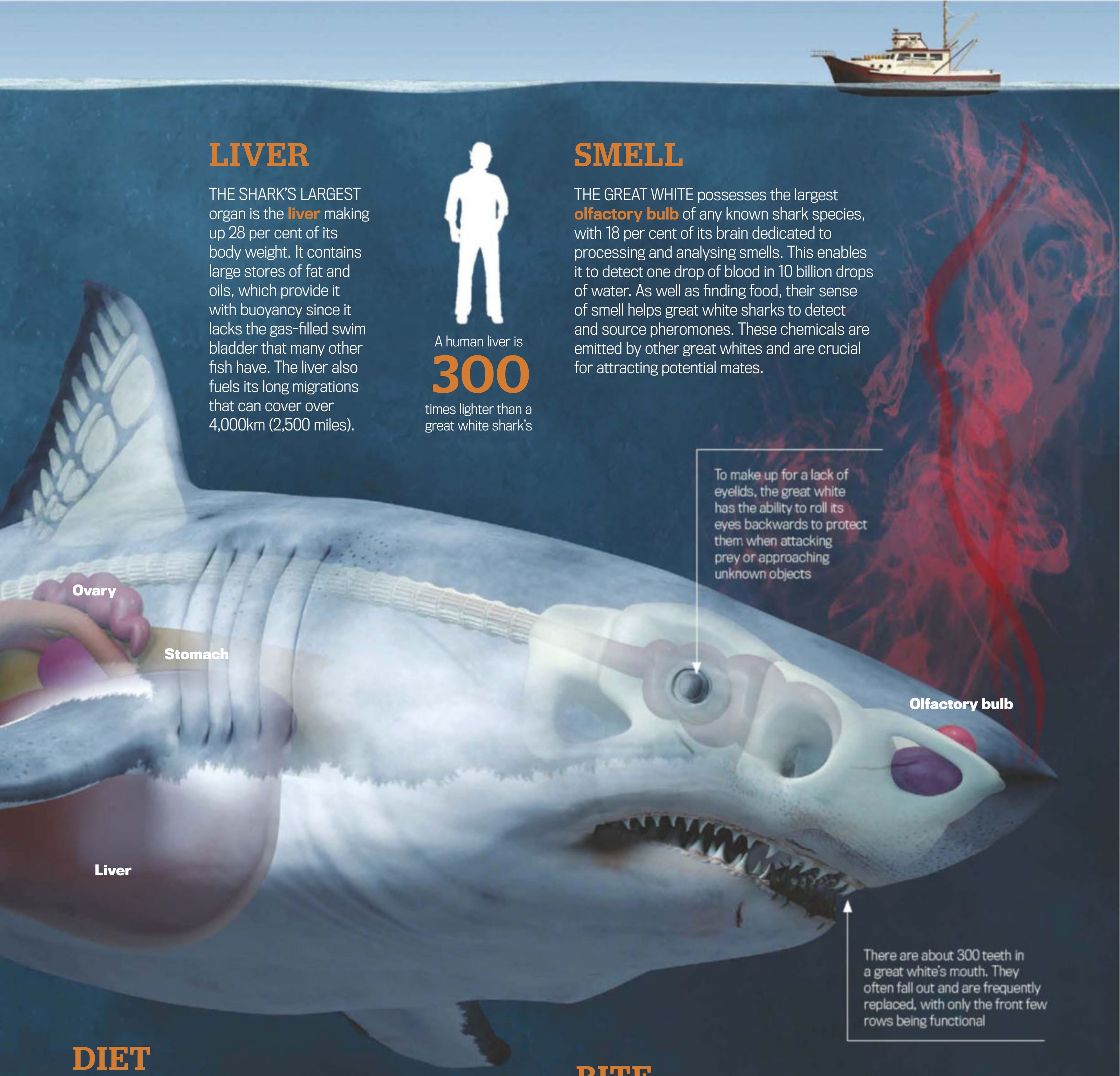
A human liver is

300

times lighter than a great white shark's

SMELL

THE GREAT WHITE possesses the largest **olfactory bulb** of any known shark species, with 18 per cent of its brain dedicated to processing and analysing smells. This enables it to detect one drop of blood in 10 billion drops of water. As well as finding food, their sense of smell helps great white sharks to detect and source pheromones. These chemicals are emitted by other great whites and are crucial for attracting potential mates.



To make up for a lack of eyelids, the great white has the ability to roll its eyes backwards to protect them when attacking prey or approaching unknown objects

There are about 300 teeth in a great white's mouth. They often fall out and are frequently replaced, with only the front few rows being functional

DIET

THE GREAT WHITE typically feeds on seals and sea lions. It attacks in a rapid movement from below and behind, causing massive trauma. It then retreats to a safe distance; once the seal is dead, the shark returns to feed. The high fat content of these animals provides a good source of energy for the shark. But great whites will scavenge too, and have been seen chowing down on the carcasses of whales.

2,187

tins of tuna weigh the same as a male sea lion – a tasty meal for a great white

BITE

THE HIGHEST BITE force in the animal kingdom belongs to the great white, and is equivalent to at least 1.8 tonnes. They can maintain this force regardless of how wide their jaws are open due to a unique arrangement of muscles. They are unable to use these jaws to their full effect until they have developed enough 'mineralised cartilage', which most great whites don't achieve until they are three metres in length.

3

times more bite force is exerted by a great white than an African lion

BBC ONE
Don't miss *Shark* on iPlayer this month

PHOTO: SCIENCE PHOTO LIBRARY

WHERE ARE ALL THE HABITABLE PLANETS?

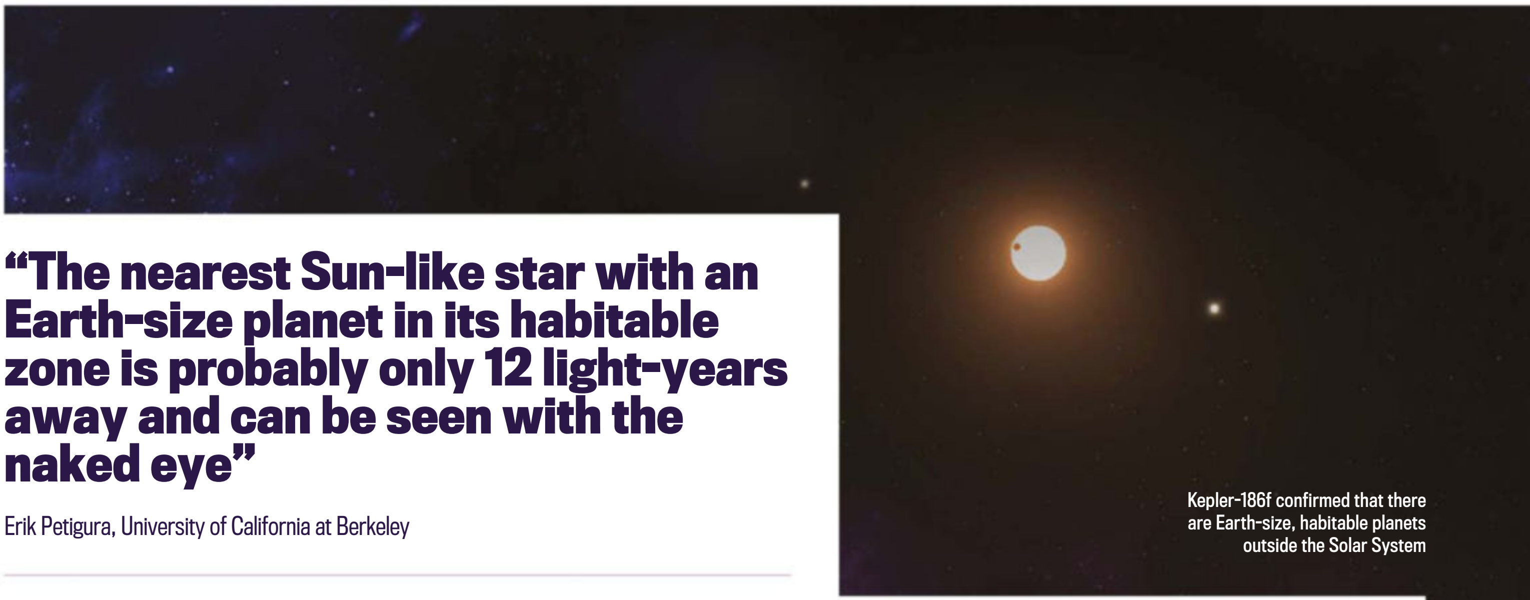
The number of known planets is increasing all the time, but how soon can we expect to find life? **Stuart Clark** takes a closer look

Artist's impression of an alien planetary system in the Andromeda galaxy

BACK IN MARCH, a team at the Niels Bohr Institute in Copenhagen used a 250-year-old equation called the Titius-Bode Law to predict the number of habitable planets. The researchers stated that billions of stars will have one to three planets in their 'Goldilocks Zone', also known as a habitable zone (see p54). While the law gives a simple means of predicting the orbits of planets around a star, it isn't particularly accurate – even when applied to the Solar System.

Still, a lot of researchers believe that there are a significant number of Earth-like planets out there somewhere, many even within the Milky Way. Astronomers call these Earth-like planets 'Earth analogues'. At the time of writing, there are 1,211 known planetary systems, with 482 of those sporting more than one planet. The current total of known planets sits at 1,918. These numbers increase all the time as new discoveries are made by various space programmes. Some of the planets so far observed are Earth-sized, some are in similar orbits to Earth, and some are around Sun-like stars. But not a single one ticks all three of these criteria. Astonishingly, of these hundreds of planets, not one is Earth's twin. Does this mean that Earth analogues are rare? With several missions planned for the coming years by NASA and others, will we soon find our planet's sibling?

Prof Geoffrey Marcy, from the University of California at Berkeley, was one of the first people to find planets around other stars. Back in 1995, he began reporting a string of planetary discoveries that continues to this day. In 2013, he and two colleagues began to wonder how close the nearest Earth-twin might be.



“The nearest Sun-like star with an Earth-size planet in its habitable zone is probably only 12 light-years away and can be seen with the naked eye”

Erik Petigura, University of California at Berkeley

Kepler-186f confirmed that there are Earth-size, habitable planets outside the Solar System

To find out, they trawled through data collected by the Kepler telescope. Launched in 2009, it continually monitored 145,000 stars until 2013, when a malfunction in its guidance system ended the mission. Marcy and colleagues analysed data from 42,000 stars in the survey. The signature they were looking for was a dimming in the star’s light. When a planet passes in front of its parent star, its silhouette dims the star slightly and the telescope can measure this.

Using this technique, they discovered 603 planets. Ten were more or less Earth-sized and received something comparable to the light that Earth receives. None of the planets were Earth’s twin, but in analysing the results statistically, they reached the conclusion that one in five Sun-like stars could harbour an Earth analogue.

“When you look up at the thousands of stars in the night sky, the nearest Sun-like star with an Earth-size planet in its habitable zone is probably only 12 light-years away and can be seen with the naked eye. That is amazing,” said UC Berkeley graduate student Erik Petigura, who led the analysis of the Kepler data.

To help quantify the Earth-like properties of a planet, astronomers have concocted the Earth Similarity Index (ESI). It looks at a planet’s radius, density, escape velocity and surface temperature and compares it to Earth. Planets are given a grade on a scale between 0 and 1, with a score of 1 indicating a planet exactly like Earth.

Using this scale, the planet most similar to Earth is KOI-1686.01. KOI stands for Kepler Object of Interest and is a temporary designation

EXPLAINED: THE ‘GOLDILOCKS ZONE’

This is the region around a star where the atmospheric conditions for orbiting planets are ‘just right’ to support liquid water. The exact location of the zone varies depending on how hot the star is…

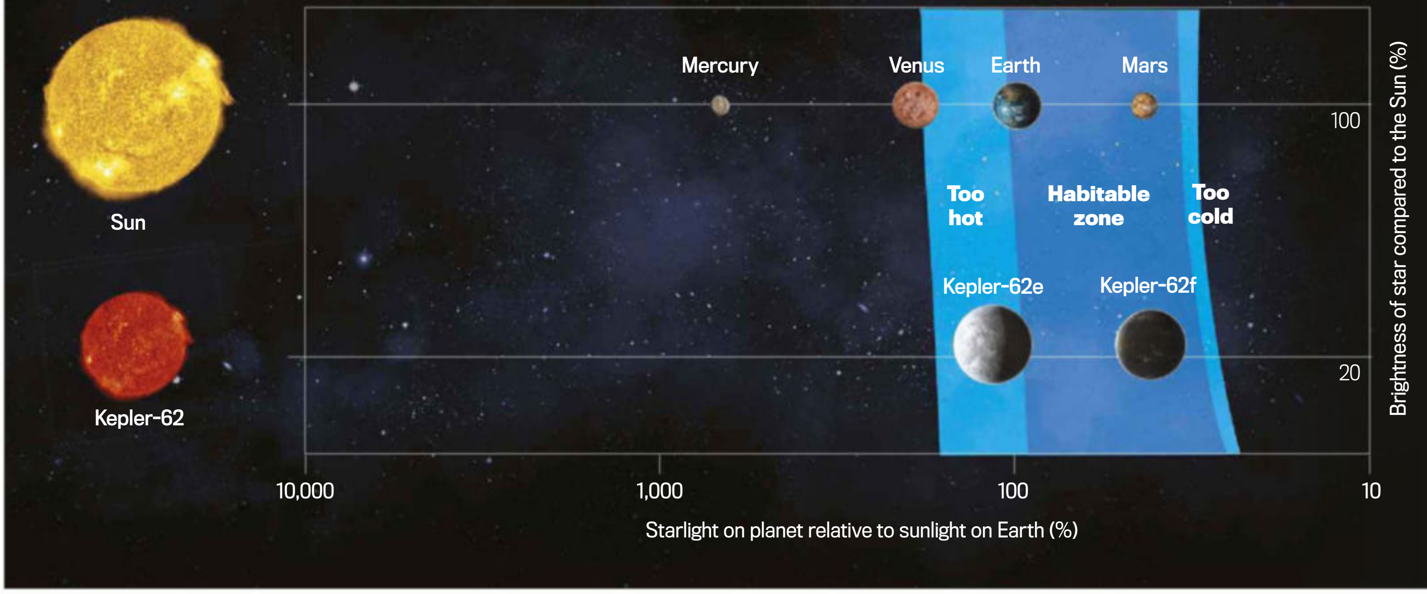


PHOTO: NASA/KEPLER, JOHN D & CATHERINE T/ MACARTHUR FOUNDATION

given to planet candidates before they are confirmed. In this case, KOI-1686.01 is 1.33 times the radius of Earth. Although it orbits a dim red dwarf star, it is so close that it receives enough heat to allow surface water to be liquid. When everything was evaluated, its ESI came out to be 0.89. In our own Solar System, Mars has an ESI of just 0.69. Unfortunately, follow-up observations have failed to spot the planet for a second time.

WATER WORLD

To be counted as real, a planet must be seen first as a dimming of the star, and then

Prof Sara Seager is confident that if there are Earth-like planets out there, her team will find them

EARTH 2.0?

Kepler was specifically designed to scan our region of the Milky Way for planets in the habitable zones of their central stars. Here are a few candidates that could support life…

Artists' impressions of some of the exciting exoplanets orbiting stars other than our own

KEPLER-438b

This planet was confirmed on 6 January 2015. Kepler-438b is thought to be a rocky planet and is just 1.12 times the radius of Earth. It is situated 470 light-years away, where it orbits a red dwarf star once every 35.2 days. Even though its star is cooler than the Sun, its close proximity means that it receives 1.38 times the solar energy that Earth does.

KEPLER-442b

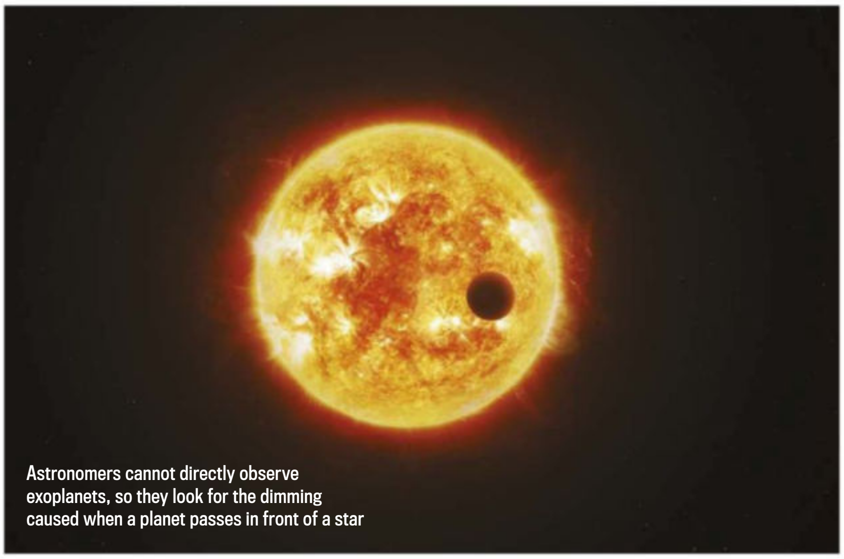
This planet is 1,120 light-years from Earth and 1.34 times our planet's radius. Although its parent star is a little cooler than the Sun, the planet's orbit means that it receives 0.66 of Earth's input energy. Kepler-442b orbits its parent star once every 112 days. Its discovery was announced at the same time as Kepler-438b.

confirmed using a ground-based telescope to look for the wobble on the star that the planet's gravity causes.

So, no second Earths yet. But that doesn't mean that some of the planets so far detected cannot be habitable. They'd just be more like Earth's cousins than Earth's twins. “For me, two planets stand out head and shoulders above all the others,” says Marcy. “The first is Kepler-186f. This is almost exactly Earth-sized but only receives about one-third of the warmth from its star that Earth receives from the Sun. The second is Kepler-62f. This is 1.4 times bigger than Earth and receives around 40 per cent of Earth's energy.”

Habitability rests, first and foremost, on the planet being warm enough for liquid water to exist so that biochemical interactions can take place. A planet receiving much less energy than Earth receives from the Sun may seem as if it is too cold, but a planet's atmosphere can play a big role.

> **“If there is a rocky planet transiting a small star in the habitable zone of that star, we will find it”**
>
> Prof Sara Seager, Massachusetts Institute of Technology



Astronomers cannot directly observe exoplanets, so they look for the dimming caused when a planet passes in front of a star

PHOTO: NASA/AMES/CALTECH X4, DAVID A AGUILAR/CFA, ESA/C CARREAU, ESA/ATG MEDIALAB

We hear a lot about the greenhouse effect, which is an atmosphere's ability to trap heat. Because of its association with industrial waste gases, we tend to think of it in a negative way, yet we rely on the greenhouse effect's warming action to keep the Earth habitable.

“Earth would be freezing without a greenhouse effect,” confirms Marcy. So his two choices would have to rely on a greenhouse effect to compensate for the lack of energy they receive directly. In the case of Kepler-62f, its larger size will generate more gravity, thus ensuring a thicker atmosphere than Earth, which boosts its greenhouse effect.

A new generation of searches for habitable planets is on the horizon, with two new space missions that will follow on from the techniques of Kepler. They are being developed on either side of the Atlantic, and both rely on the transit method of detection. More sensitive telescope detectors will allow smaller planets to be seen.

The European Space Agency (ESA) is building CHEOPS (CHaracterising ExOPlanet Satellite) for launch in 2017. It will study nearby star systems

KEPLER-186f

Kepler-186f was announced in April 2014 and is perhaps the closest match to Earth so far. Although some began dubbing it Earth 2.0, it's not identical. While it is 1.1 times the radius of Earth, its star is dimmer than the Sun and Kepler 186f receives just a third of Earth's input energy. It was the first Earth-size planet to be found orbiting in the habitable zone of a star.

KEPLER-62f

This is the outermost of a five-planet system orbiting the star Kepler-62. At 1.4 times the radius of our planet, it is termed a super-Earth. It receives just 0.41 times the amount of solar energy of the Earth, but its extra bulk will provide more gravity to attract a thicker atmosphere that could give rise to a lifesaving greenhouse effect.

KEPLER-62e

This planet is a sister world to Kepler-62f and is another super-Earth. It is located at the inner edge of the star's habitable zone so it receives more energy than the Earth. The discovery of the two potentially habitable worlds around Kepler-62 prompted a congressional hearing in the US dubbed 'Exoplanet Discoveries: Have We Found Other Earths?'.

that are already known to have planets, with a goal of measuring those planets' radii and to look for other worlds that have so far escaped detection.

A CLOSER LOOK

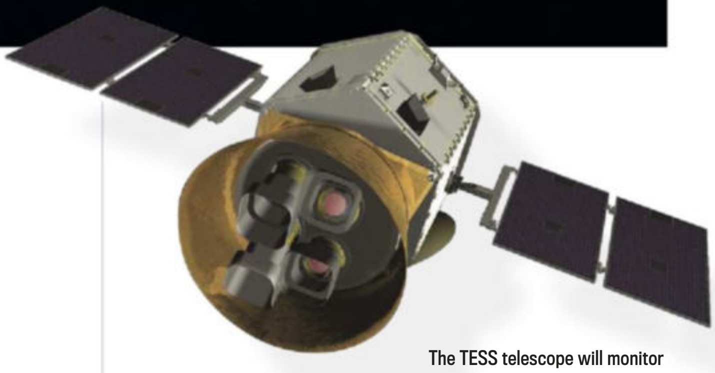
Simultaneously, NASA is planning the Transiting Exoplanet Survey Satellite (TESS). This too will launch in 2017. It will use four onboard wide-angle telescopes to survey half a million stars across the sky. The mission team estimates that TESS could find between 1,000-10,000 planets.

The driving scientist behind TESS is Prof Sara Seager of the Massachusetts Institute of Technology. She is in no doubt about the goals and abilities that TESS will have. "If there is a rocky planet transiting a small star in the habitable zone of that star, we will find it," she says.

She hit the headlines in 2013 by describing an equation that could be used to estimate how many planets with detectable signs of life may be discovered over the coming years.

The various terms in the expression included the number of stars to be observed, the fraction of those stars that we expect to have planets in their habitable zone, and the fraction that have sufficient life to produce an observable signature. Seager estimated that some terms, like the number of stars observed, can be assigned real values. But other terms, such as the fraction that have detectable life signs, remain speculative. As a result, her equation cannot give a definitive answer but she still believes that it was still a worthwhile exercise. "I wanted the world to know that we are doing the real search for alien life," she says.

The first step towards that goal is finding as many habitable planets as possible. Astronomers already have some in the bag, but CHEOPS and TESS should advance the search significantly. E.T. – we're coming! ■



The TESS telescope will monitor half a million stars for planets in their habitable zones

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STUART CLARK is an astronomy writer and author of the forthcoming *The Unknown Universe: What You Need To Know About Time And Space*

Find out more

BBC RADIO 4 92–95FM & 198LW

To listen to an episode of *In Our Time* about exoplanets, visit **http://bbc.in/19baixZ**

CAN YOU CATCH THE PLAGUE?

In Europe, we think of the plague and other medieval diseases as relics from the past. **Russell Deeks** investigates how scientifically likely you are to catch them

RING-A-RING o' rosies,
a pocket full o' posies.
A-tishoo! A-tishoo!
We all fall down.

For most of us, this deceptively macabre nursery rhyme is the sole legacy of the bubonic plague, a killer disease that once wiped out a quarter of Europe's population. Bubonic plague has, we tend to assume, been safely relegated to the dustbin of medical history.

Except that's not true. Europe may have been largely free of the disease since the early 18th Century, but unlike smallpox, it's never been truly eradicated. Outbreaks of bubonic plague still occur fairly regularly in the developing world, while even in the USA there are seven cases a year, on average. So should we be worried?

HORRIBLE HISTORY

Bubonic plague is caused by the bacterium *Yersinia pestis*. This rod-shaped, anaerobic microbe lives in the guts of fleas, which in turn live on small rodents including rats, gerbils and prairie dogs. Should an infected flea then bite a human being, the bacterium attacks the lymph glands in the armpits and groin, causing the characteristic swellings – buboes – that give the disease its name. Sufferers also experience flu-like symptoms: severe fever, chills, muscle cramps, aching limbs, coughing and difficulty breathing. Gangrene and haematemesis (vomiting blood) can also occur.

If untreated, 60 per cent of victims will die within a few days. If antibiotics are given within 24 hours of symptoms appearing, however, the mortality rate drops to less than 15 per cent.

If the infection spreads to the bloodstream, it is known as septicaemic plague; if it spreads to the lungs, it becomes pneumonic plague. The latter is particularly troublesome because this form of the disease can be spread directly between humans.

There have been three major plague pandemics. The first, the Plague of Justinian, occurred in the 6th Century in the Byzantine Empire. This killed an estimated 25 million people, with another 25 million dying in smaller outbreaks over the next 200 years. The second, the Black Death, spread right across Europe in the mid-1300s, killing 200 million. The third pandemic, in the late 19th and early 20th Centuries, was largely confined to Asia and the Far East, and killed 12 million people in China and India alone. The Great Plague of London that occurred from 1665 to 1666 was a mere sideshow in comparison. It saw 100,000 people – 25 per cent of the city's population – die of the disease.

The third pandemic was not officially declared over until the 1950s. Yet outbreaks still occur, with the majority occurring in sub-Saharan Africa. In Zambia, for instance, an outbreak in 1997 caused 26 deaths.

Very recently, bubonic plague hit China and Madagascar. In July 2014, the 30,000 inhabitants of Yumen, in the Chinese province of Gansu, found their town closed off from the world after a 38-year-old man died from the disease. Then, between August 2014 and February 2015, 71 people died from plague in Madagascar. This island sees fairly regular occurrences of the disease, partly due to slum conditions.

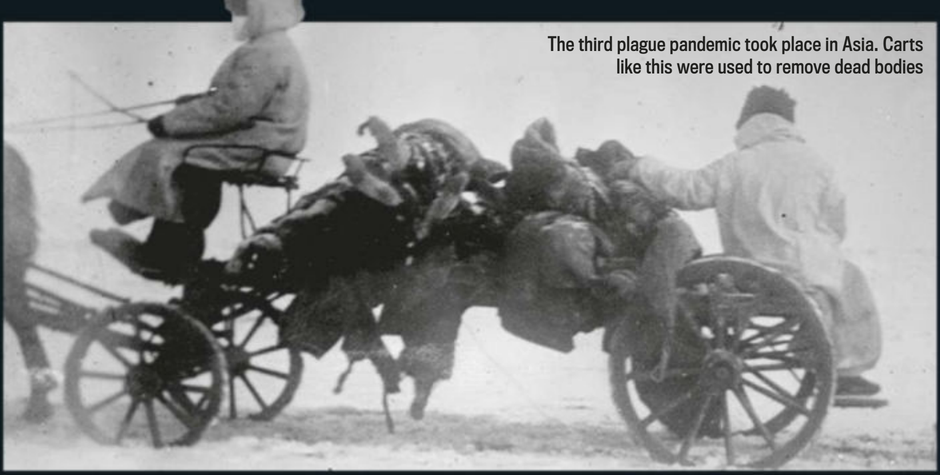
> **"We found a total of 545 fleas on only 133 rats. It was quite a surprise to find so many"**
>
> Matthew Frye from Cornell University's New York State Integrated Pest Management Program

PLAGUE IN THE USA

Recently, plague watchers' eyes have turned to New York City, thanks to two separate studies that found risk factors for the disease. A study led by Matthew Frye of Cornell University's New York State Integrated Pest Management Program found Oriental rat fleas – the type that carry the *Y. pestis* bacterium – on NYC rats, while one carried out by Cornell's medical school found the *Y. pestis* bacterium itself on the city's subway. However, no infected fleas or rats were found, so no need for New Yorkers to panic just yet...

"We sort of expected to find Oriental fleas because we knew that historically they were in the city, but what surprised us was the number. We found a total of 545 fleas on only 133 rats," says Frye. "It was quite a surprise to find so

Bubonic plague can inhibit circulation to the tissues, causing the affected area to rot and die



The third plague pandemic took place in Asia. Carts like this were used to remove dead bodies

PHOTO: ISTOCK X6, SCIENCE PHOTO LIBRARY, US LIBRARY OF CONGRESS

many. But none of the fleas were carrying the plague bacterium, and none of the rats had plague. The other study found a number of strange bacteria in the subway system that they didn't expect to, but this is still a developing area of study. We don't yet know how that translates to human disease, whether these things that are found on structures and surfaces are being acquired by humans or cohabiting organisms. But we do know it's not easy for any animal, whether a rat or a human, to pick up plague bacteria that are in the environment."

But what if the bacterium were to evolve? A third study, carried out in 2014 by a team led by Dave Wagner, from the Center for Microbial Genetics and Genomics at Northern Arizona University, looked at how the bacterium itself has evolved over time, concluding that different pandemics were caused by different strains of *Y. pestis*.

"We used teeth from suspected victims of the first pandemic," says Wagner. "Teeth are

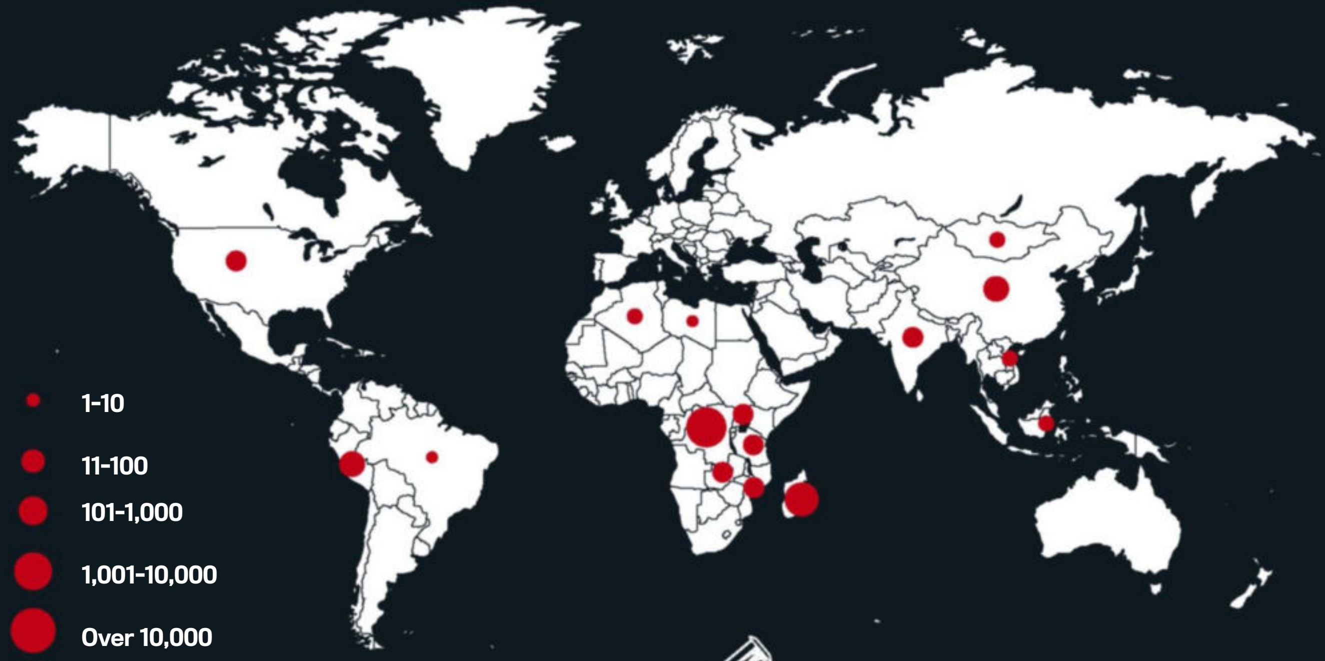
PHOTO: C FIRTH, MCMASTER UNIVERSITY X2, GETTY, SCIENCE PHOTO LIBRARY X3, WELLCOME TRUST COLLECTION

Matthew Frye scoured New York in his hunt for Oriental fleas

Teeth from plague victims contain DNA from *Yersinia pestis*

THE PLAGUE IN NUMBERS

REPORTED PLAGUE CASES BY COUNTRY 2000-2009



New research suggests that gerbils, rather than rats, could have caused the spread of the Black Death

Vaccines are available, but are not very effective in combatting plague. They are used by lab and field personnel working with the disease

1900

The first case of plague in the US occurred at the turn of the 20th Century. The disease arrived from the San Francisco docks

Using teeth, scientists established that three different strains of the plague bacterium caused the three historical pandemics

a good sample for obtaining DNA of blood-borne pathogens as you have a lot of blood vessels feeding your dental pulp. Teeth act as a sort of time capsule for ancient DNA. Most of the DNA in the sample will obviously be human, but if the person died of plague there will be some *Y. pestis* DNA in the sample as well. So we 'pulled' the *Y. pestis* DNA out of the total DNA," he explains.

"We found that the three pandemics were definitely caused by different strains," Wagner continues. "But we also found that the strains associated with the three human pandemics are pretty much identical in their DNA to the *Y. pestis* strains found around the world today in different rodent populations. That suggests that pretty much all *Y. pestis* strains are capable of causing pandemics given the right conditions. The reason we don't have pandemics any more isn't because *Y. pestis* has changed, it's because human behaviour has changed."

DON'T HAVE NIGHTMARES

And that, in a nutshell, is why you needn't worry too much. Even if an outbreak of plague were to occur, as Wagner points out, "We now have antibiotics, and plague is easily treated with almost any antibiotic." Or as a World Health Organization fact sheet puts it: "Early diagnosis and treatment is essential for survival and reduction of complications [but] antibiotics and supportive therapy are effective against plague if patients are diagnosed in time."

More importantly, now that the mechanism of plague contagion through fleas and rodents is understood, keeping the disease under control is simply a matter of good hygiene and sanitation.

In other words, if you don't want to die like a medieval peasant... try not to live like one. ■

RUSSELL DEEKS is a freelance science and technology journalist

DARK AGE DISEASES

Bubonic plague isn't the only medieval killer that's still lurking in the shadows...

Charles II touching King's Evil sufferers

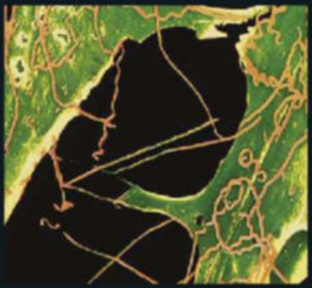
THE KING'S EVIL

So-named because it was believed being touched by the King would cure you, the King's Evil caused large, black swellings all over the sufferer's neck. Today we know this to be scrofula, a swelling of the lymph nodes due to infection by tuberculosis or other mycobacteria. With surgery and antibiotics, complete remission occurs in 95-100 per cent of patients – though it remains a danger to those suffering from AIDS.

Convulsions caused by ergot poisoning

ST ANTHONY'S FIRE

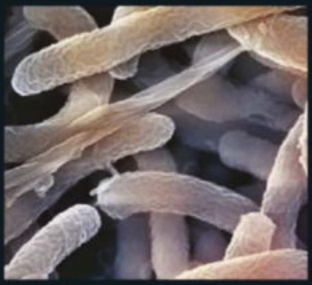
An epidemic in Paris in 945 AD saw huge numbers of victims covered in raw, red sores all over their bodies and afflicted by hallucinations, convulsions and gangrene. We now know that this was caused by poisoning due to long-term exposure to ergot – a fungus that affects rye, barley and other cereals. This fungus can now be detected and eradicated in cereal crops. In the modern world, the disease is now vanishingly rare.



Treponema pallidum causes syphilis

FRENCH POX

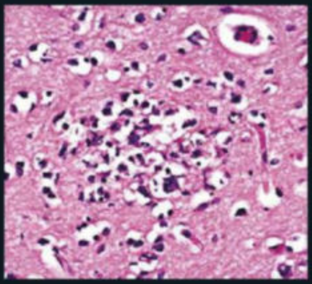
Otherwise known as syphilis, this is a sexually transmitted infection that causes lesions first on the sexual organs, then all over the body, along with fever, sore throat, headaches, rashes, liver inflammation and kidney disease. Basically, you don't want it. While infection isn't uncommon – with around 50,000 new cases in the US each year – it can now be treated with antibiotics. These days, fatalities are rare, though lasting organ damage can occur.



Cholera bacteria infect the gut

CHOLERA

This is caused by the ingestion of faecal bacteria, largely from contaminated drinking water. Symptoms include vomiting, muscle cramps and diarrhoea, leading to severe dehydration. If untreated, the mortality rate is as high as 50 per cent. During the 19th Century, six successive pandemics killed millions. Prevention, through access to clean drinking water, is the best cure, but cholera still kills upwards of 100,000 people worldwide a year.



Typhus is caused by *Rickettsia* bacteria

TYPHUS

Typhus – not to be confused with typhoid fever – is spread by lice and fleas carrying *Rickettsia* bacteria. It causes high temperature and pain throughout the body. If untreated, the mortality rate can reach 60 per cent. The first known epidemic occurred during 1489's Siege of Granada, when it killed 17,000 Spanish troops. The first vaccines were developed in the 20th Century, but it's still a problem in the developing world.

WASTE NOT, WAN

8

TRANSPORT FUEL

METHANE IS A simple product that can be created from human faeces. The main ingredient in the natural gas that is tapped from the ground before running throughout the national grid, methane heats our homes and cooks our food. But it can also be produced in anaerobic digesters, in which microbes degrade food scraps and other organic material in the absence of oxygen. Methane can even be made straight from sewage. To prove that 'not everything we flush goes to waste', the FirstGroup transport company is running the first bus in the UK powered by poo. The Bio-Bus – launched in March 2015 – uses biomethane provided from the GENeco waste recycling and renewable energy facility in Avonmouth. The 41-seater bus runs along the aptly named number 2 route that links Cribbs Causeway in north Bristol to the south of the city.

The innovative vehicle can run for up to 300 kilometres on one tank (the equivalent of five people's annual flushes). If successful, and if riders approve of travelling on human emissions, the company hopes to roll out even more 'poo buses'.

PHOTO: GENECO, DUNCAN KINNEY/GREEN ENERGY FUTURES

T NOT

Each day, we could be flushing millions of pounds down our collective loos. **Zoe Cormier** examines eight ways the world can harness human waste

The gas is stored in the top of the Bio-Bus. Its CO_2 emissions are around 20-30 per cent lower than those from diesel

7

ANIMAL FEED

AN INNOVATIVE FEED for farm animals is being developed by researchers at the Sanitation Ventures group at the London School of Hygiene & Tropical Medicine. Their work is largely funded by the Bill & Melinda Gates Foundation's Reinvent the Toilet Challenge, which is aimed at helping the 2.5 billion people worldwide who lack sanitation.

According to Dr Jeroen Ensink, Senior Lecturer in Public Health Engineering at the London School of Hygiene & Tropical Medicine, they wanted to find a way to safely remove the human waste from latrines, but also generate a bit of income for these communities. Their solution was to use black soldier fly larvae to degrade the human waste. The plump larvae were then turned into a protein-rich product to be sold as fish food or chicken feed. Tests to see if meat and eggs that derive from human faeces-fed larvae are safe for consumption are taking place right now, says Ensink.

These dried black soldier fly larvae can be used for animal feed

6

RADIATION SHIELDS

WHILE NASA SHELVED its plans for a base on Mars, and later its intentions for a lunar station, others have not given up on the interplanetary dream of putting humans on other planets. Mars One, for example, aims to send humans to a permanent base on Mars by 2026. Meanwhile, Inspiration Mars – a private venture founded by American Dennis Tito – plans to send adventurers on flyby missions to the Red Planet by 2018.

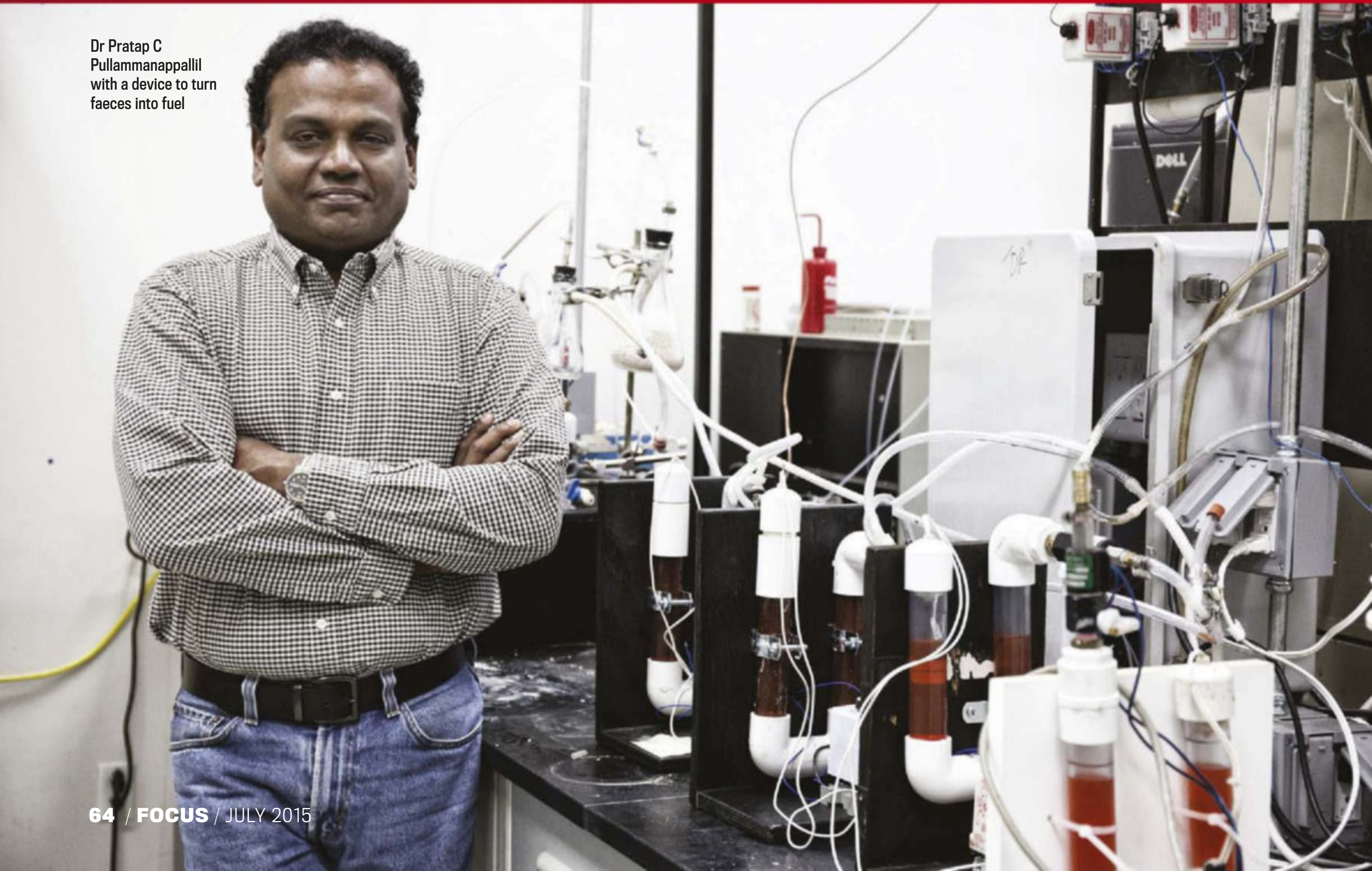
One of the greatest hazards of interplanetary travel will be cosmic radiation, which is estimated to increase the risk of cancer by 3 per cent. Inspiration Mars's solution? Line the walls of the space shuttle with water, food, and excrement. Could the power of poo really help us conquer the cosmos? Perhaps Oscar Wilde put it best: "We are all in the gutter, but some of us are looking at the stars."

Interplanetary travellers could visit Mars via a poo-lined space shuttle

5

ROCKET FUEL

IN SPACE, WHAT do you do with your poo? Early astronauts simply bunged their dung in a bag. This proved inadequate, and led to some unfortunate situations. Back in 1969 on NASA's Apollo 10, Commander Tom Stafford is quoted as saying: "Give me a napkin, quick. There's a turd floating through the air." Modern space loos are more sophisticated, yet they make the same mistake: not putting those turds to good use. Instead, scientists from the University of Florida suggest that lunar bases could convert faeces into fuel. They came up with a technique that would enable 290 litres of methane to be produced per astronaut per day – enough to power their rocket back to Earth. As a bonus, water from waste could be split into hydrogen and breathable oxygen. "We began working on this idea back in 2002, when NASA wanted us to help them plan for using waste for fertiliser and fuel in a base on Mars," says Dr Pratap C Pullammanappallil, who worked on the research.



Dr Pratap C Pullammanappallil with a device to turn faeces into fuel

Microbial fuel cells convert urine to electricity

3

POO TO PLATE

THE SIMPLEST WAY to make good use of waste is to use faeces as fertiliser. Throughout history, human waste has been used on fields in nearly every culture on Earth. Today, the thought of using our own excrement to grow food may seem revolting, but the tradition continues in developed countries. For example, roughly 60 per cent of biosolids – the sterilised end-products of wastewater treatment facilities – are spread onto land in the US (usually fallow fields or tree plantations). In developing countries, however, untreated sewage is frequently taken from open pit latrines and used on farmland. While raw sewage is cheaper than traditional fertilisers, its usage can often lead to increased numbers of microbes and parasites. Thankfully, safer solutions are being devised. One innovative example is the Tiger Toilet, which is being developed at the London School of Hygiene & Tropical Medicine. The simple loos are filled with tiger worms that can convert poo to compost in about six months.

Tiger worms eat poo and create compost

4

PEE POWER

POO ISN'T THE only powerful excretion – there is a urinal at the University of the West of England that can generate electricity from pee. The unit, which is partly funded by Oxfam, could bring power to off-grid locations such as refugee camps. The urinals contain microbial fuel cells, which are filled with live microbes that feed on urea. The system accesses the biochemical energy the microbes use for growth and converts it to electricity.

"This first step shows we can power lights inside the cubicle," says Prof Ioannis Ieropoulos, from the Bristol BioEnergy Centre at the university. "The next challenge is generating enough electricity to go beyond the urinal." Their research – which began 13 years ago – did not start with pee. The team initially investigated potential fuels for autonomous robots and examined the electricity that could be produced with various waste materials, such as grass clippings and shrimp shells. "Urine actually proved to be one of the best feedstocks for electricity production," says Ieropoulos.

> **"This first step shows we can power lights inside the cubicle. The next challenge is generating enough electricity to go beyond the urinal"**
>
> Prof Ioannis Ieropoulos, Bristol BioEnergy Centre at the University of the West of England

PHOTO: MARS ONE, OXFAM, AMY STUART/UF IFAS COMMUNICATIONS

2

HYDROGEN FUEL

THE HYDROGEN IN hydrogen fuel cells is obtained via the electrolysis of water. A current is passed through water to obtain hydrogen and oxygen molecules. Using the same technique, oxygen and hydrogen can be cleaved from ammonia and urea – two of the main compounds in pee. In fact, the process is far more efficient with urine because less energy is required to obtain the substances.

Researchers at the University of Ohio are looking to harness this power in urine to generate electricity from large buildings, such as offices and sports stadiums. Meanwhile, a team at Caltech (another Bill & Melinda Gates Foundation winner) is working on solar-powered urinals with the capacity to generate hydrogen gas that can be stored as a back-up source of energy. One problem: researchers have waxed lyrical over the promise of the hydrogen economy for decades, with few results. Are these hydrogen visionaries just pissing in the wind? Time will tell.

Caltech graduate student Clement Cid with the team's solar-powered urinal

University of Ohio researchers with their 'S-pee-d Racer' car, which runs on hydrogen extracted from urea

PHOTO: HEATHER LOWERS/USGS DENVER MICROBEAM LABORATORY, CALTECH, ISTOCK X2, ALAMY, UNIVERSITY OF OHIO

1

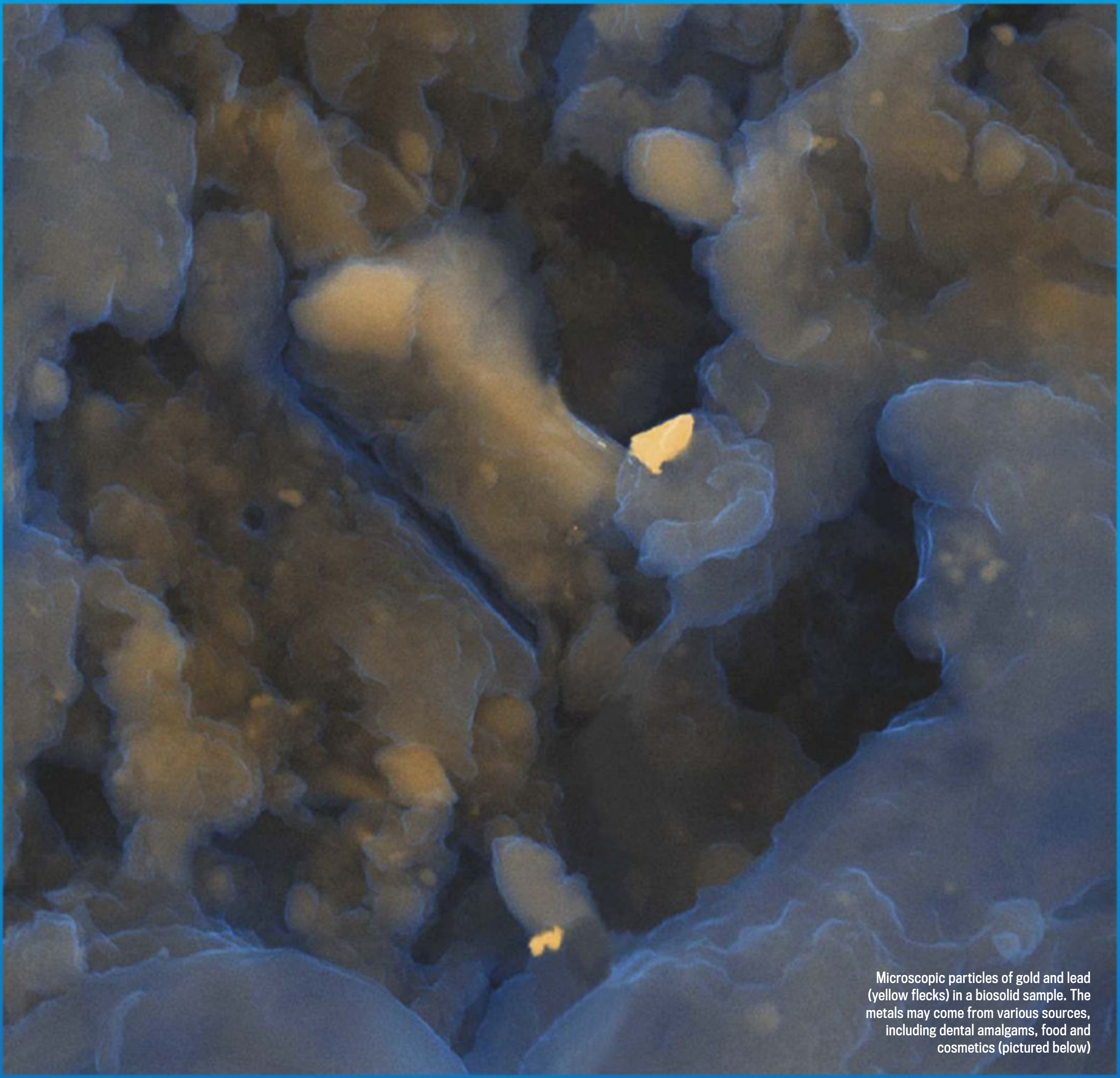
MINE FOR GOLD

TALK ABOUT TURNING trash to treasure: scientists are looking at ways to extract precious metals – including gold, silver, platinum, copper and titanium – from sewage. What's more, the amount is far from insubstantial: the waste produced by a million Americans every year could contain as much as $13m worth of metals. According to Dr Paul Westerhoff from Arizona State University, it's unclear exactly where these metals are coming from because municipal sewage derives from more than just domestic origins. Waste from dentists' offices is one likely trove because gold and silver is used in dental amalgams, while other potential sources are the cosmetics and personal care products that go down the drains.

But poo could also be serving up the goods: titanium dioxide, for example, is added to many doughnuts. Whatever the source, more research is needed to figure out where the metals are coming from and how to extract them. "If we really can mine $13m per year from a community of a million people, we could not only reduce the cost of treating municipal waste, we could also reduce the need to mine these metals from traditional sources," says Westerhoff. "By reducing the need for mining, reducing the amount of metals that wind up on land and in forests as biosolids, and extracting something of value that reduces overall treatment costs, it's a potential big win."

This all points to a much bigger issue. Just as we now increasingly view paper, plastic and metal waste from households as a resource to be recycled rather than rubbish to be discarded onto landfills, we may need to think of our own excrement in the same way. We could call it urban mining, perhaps? Dr Jeroen Ensink of the London School of Hygiene & Tropical Medicine agrees. "We can only tackle the sanitation problem when we make it a commercial success. Only when you can turn waste into an asset will people start investing in its proper treatment."

But is it really possible to extract these precious metals from faeces? "I have already told one of my PhD students that she won't graduate until she gives me a gold ring made in this way," chuckles Westerhoff. ■



Microscopic particles of gold and lead (yellow flecks) in a biosolid sample. The metals may come from various sources, including dental amalgams, food and cosmetics (pictured below)

ZOE CORMIER is a science writer with a background in biology

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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN
Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service

LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com
or post to *Focus* Q&A, Tower House, Fairfax Street, Bristol, BS1 3BN

Q **CLAIRE HILL,** PRESTON

Which fish jump the highest out of water?

A THE ATLANTIC SALMON (*Salmo salar*) can jump up waterfalls 3.7m high, but in open water the highest jumpers are all much larger fish. Some rays and marlin can leap three metres out of the water, but both are beaten by the shortfin mako (*Isurus oxyrinchus*). This acrobatic shark has been observed making jumps as high as six metres! **LV**

A fear of water is an unfortunate phobia for a ray

PHOTO: OCTAVIO ABURTO

In Numbers

15

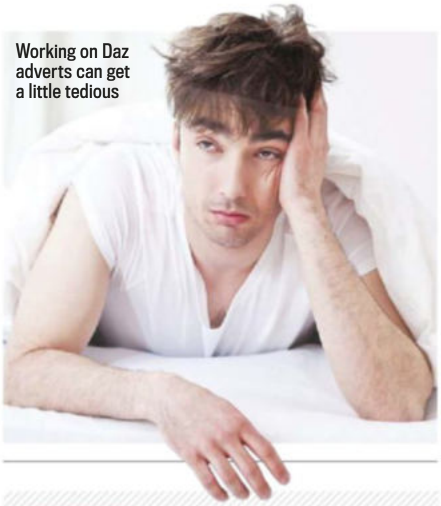
geckos were filmed playing during a 30-day space mission. It's an unusual observation as lizards don't tend to exhibit this behaviour

Q URSY REYNOLDS, GLOUCESTERSHIRE

Why do we forget our dreams so quickly?

A PSYCHOLOGISTS STILL DON'T understand the true function of dreaming. However, it almost certainly relates to memory, either by helping to consolidate the day's events or enabling us to forget unwanted detail so we don't become overloaded. In this case, recalling our dreams might not be helpful. During vivid dreaming, serotonin and noradrenaline levels are low and this might affect recall.

But perhaps the main reason is that most of our waking memories make sense and are interlinked. When I try to remember what I had for breakfast today, I can link that to memories of getting up, feeding the cats and lots of other small events. But dreams are usually illogical and their events are unrelated. So when we try to recall them, we cannot follow a sensible thread and the previously vivid details just slip away. **SB**



Working on Daz adverts can get a little tedious

In Numbers

2.3 billion

cups of coffee are drunk in the world every single day – yearly consumption has increased by 2.5 per cent since the start of the millennium

Q LOUIS ROGERS, DENFORD

Why do dogs and cats like being stroked?

A STROKING A CAT or a dog causes the hormone oxytocin to be released in both the owner and the animal, which lowers blood pressure and reduces anxiety. It also promotes a feeling of wellbeing and love in humans, so it's reasonable to assume that animals experience comparable feelings as well. But why has such a response evolved? One theory is that the domestication of animals originally offered a huge survival advantage to both humans and their pets. Humans deliberately selected the friendliest offspring from each litter, so each generation of animals grew more responsive to human contact. Plus, early humans who were animal lovers were best able to take advantage of guard dogs and pest-exterminating cats. Over time, humans and animals have co-evolved to enjoy each other's company. **LV**

You don't know where my head has been...

Q NIGEL PALMER, DUBAI

Do animals from different regions speak the same language?

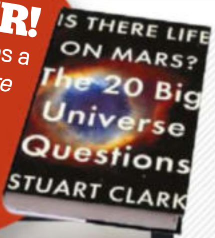
A **IT SEEMS SO. Most animals don't have a very complex vocal language to begin with, and the patterns of grunts and growls that they use to express different emotional states are all hard-coded into their genes. Some studies have found that whales, dolphins, bats, hummingbirds and even cows develop regional differences, a bit like an accent or dialect. But it's hard to be sure if animals from different populations genuinely don't understand each other. It may be that the different vocalisations are just markers that help identify which animals are 'not from round here' and therefore should be treated more suspiciously. LV**

The annual meeting of the Grass Appreciation Society was getting off to a promising start

PHOTO: ISTOCK X4, GETTY, GOOGLE EARTH X2

QUESTION OF THE MONTH

WINNER! Tony Ferrer wins a copy of *Is There Life On Mars?* by Stuart Clark (Quercus Books, £9.99)



Hold on, lads - we need to count to five first!

Q **TONY FERRER,** HIGH WYCOMBE

Is there any scientific truth in the 'five-second rule'?

A NOT MUCH. NUMEROUS studies have shown that some bacteria is transferred to food as soon as it touches the floor. Bacteria don't sense food dropped nearby and then home in on it – they get glued on by moisture and grease when the food falls on top of them.

A 2014 undergraduate study at Aston University found that the amount of bacteria was higher on food left on the floor for 30 seconds, compared with food that was picked up quickly. But this research wasn't published in a peer-reviewed journal, so it isn't clear how significant these results are. Another unpublished study at Manchester Metropolitan University found that very sweet foods like jam are actually less likely to get contaminated, because bacteria can't grow in high concentrations of sugar.

But while the exact proportion of floor bacteria that gets transferred to dropped food is interesting, it doesn't have very much bearing on how safe the food is to eat. We swim through a soup of bacteria everywhere we go. Bacteria are on every surface and we constantly pick them up with every touch. The hand that picks up your sandwich is probably just as contaminated as the kitchen counter or the floor. We are evolved to cope with these everyday germs with powerful stomach acid and an immune system to kill them off. Undercooking your chicken will give you food poisoning. Eating a chicken nugget off the kitchen floor probably won't. **LV**

Q **JOHN AWBERY,** READING

What are memcomputers?

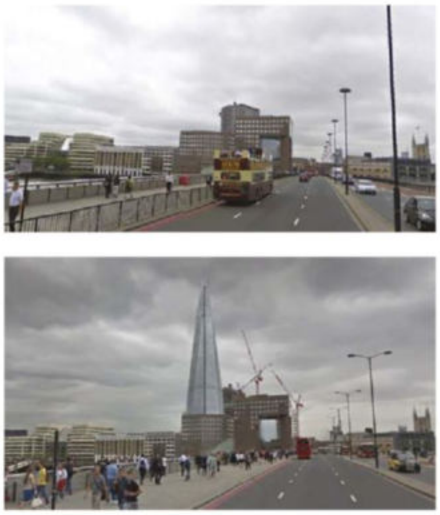
Our brains are incredibly efficient, running on just 20W

A DESPITE awesome speeds, even the fastest computers are inefficient, as they use separate parts for processing and storing information. Memcomputers can do both on a single component. Neurones also exploit this trick, allowing our brains to work effectively on just 20W of power. Companies like Intel are working on the necessary technology, but commercial viability is still years away. **RM**

Q **KEVIN GREENWOOD,** LONDON

Is Google Street View being archived?

A SINCE APRIL 2014, it has been possible to see previous versions of Street View images, some dating back to the start of the service in 2007. When historical views are available, a small clock face button appears on screen. Click that to display which images are available. For instance, the archive of London Bridge shows a non-existent Shard in 2008, a partially built one in 2012 and the completed tower in 2014. Fascinating! **GM**


Spot the difference, Google style

TOP 10

LOUDEST SOUNDS (IN AIR)

1. Volcanic eruption
Sound intensity:
Up to 310dB

2. Atomic bomb
Sound intensity:
Up to 250dB

3. Earthquake
Sound intensity:
Up to 235dB

4. Space rocket launch
Sound intensity:
Up to 190dB

5. Gunfire
Sound intensity:
Up to 180dB

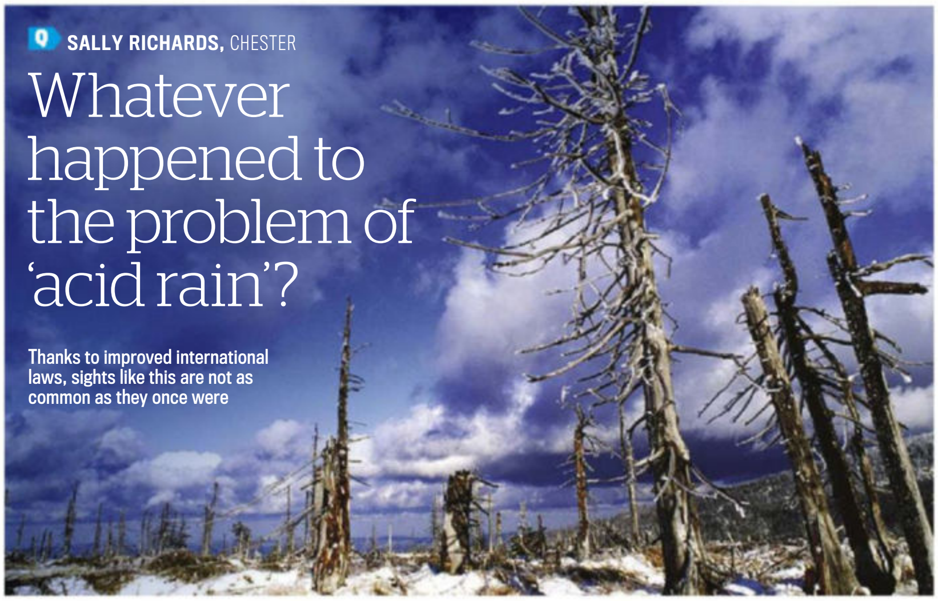
6. Fireworks
Sound intensity:
Up to 175dB

7. Dragsters
Sound intensity:
Up to 160dB

8. Jet aircraft taking off
Sound intensity:
Up to 150dB

9. Rock concert
Sound intensity:
Up to 140dB

10. Howler monkey
Sound intensity:
Up to 130dB

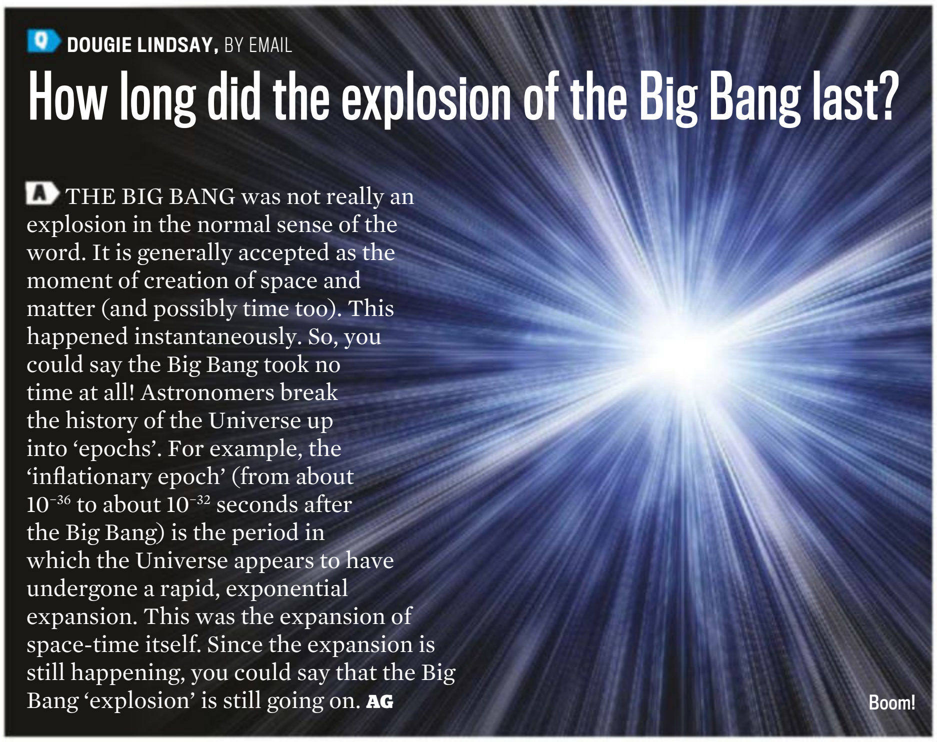


Q **SALLY RICHARDS,** CHESTER

Whatever happened to the problem of ‘acid rain’?

Thanks to improved international laws, sights like this are not as common as they once were

A DURING THE 1970s, acid rain emerged as a major environmental issue, sparking rows between neighbouring countries. Scandinavian nations blamed Britain’s power stations for creating sulphur dioxide and nitrogen-based airborne pollution that spread across the North Sea to mix with rain, causing acid damage to forests and lakes. Britain itself was affected, with a 1980 report highlighting contamination to lakes and rivers. Canada’s environmental minister once described the pollution spreading from the US as an “insidious malaria of the biosphere”. During the 1980s and 1990s, political pressure led to the introduction of international laws constraining the generation of the culprit compounds. Combined with wider use of cleaner forms of energy and improved standards of energy conservation, these measures led to substantial reduction in acid rain. In the US, the 1990 Acid Rain Program cut power station emissions of sulphur dioxide and oxides of nitrogen by over 70 per cent. Though still not entirely eliminated, the threat from acid rain is not the ecological threat it once was. **RM**



Q **DOUGIE LINDSAY,** BY EMAIL

How long did the explosion of the Big Bang last?

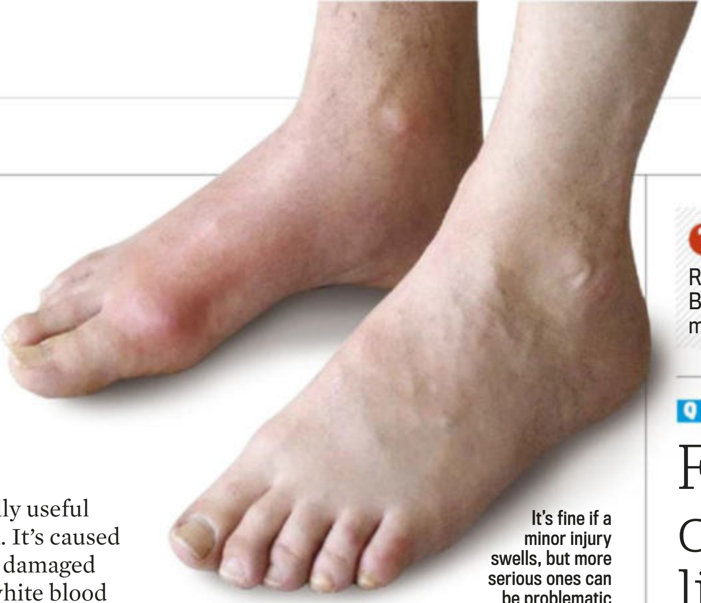
A THE BIG BANG was not really an explosion in the normal sense of the word. It is generally accepted as the moment of creation of space and matter (and possibly time too). This happened instantaneously. So, you could say the Big Bang took no time at all! Astronomers break the history of the Universe up into ‘epochs’. For example, the ‘inflationary epoch’ (from about 10^{-36} to about 10^{-32} seconds after the Big Bang) is the period in which the Universe appears to have undergone a rapid, exponential expansion. This was the expansion of space-time itself. Since the expansion is still happening, you could say that the Big Bang ‘explosion’ is still going on. **AG**

Boom!

PHOTO: ISTOCK X9, GETTY, ALAMY, SCIENCE PHOTO LIBRARY, PRESS ASSOCIATION, HAKTARFONE/WIKI

GEOFF DUNWELL, MAIDENHEAD

If swelling is bad, why does the body do it?

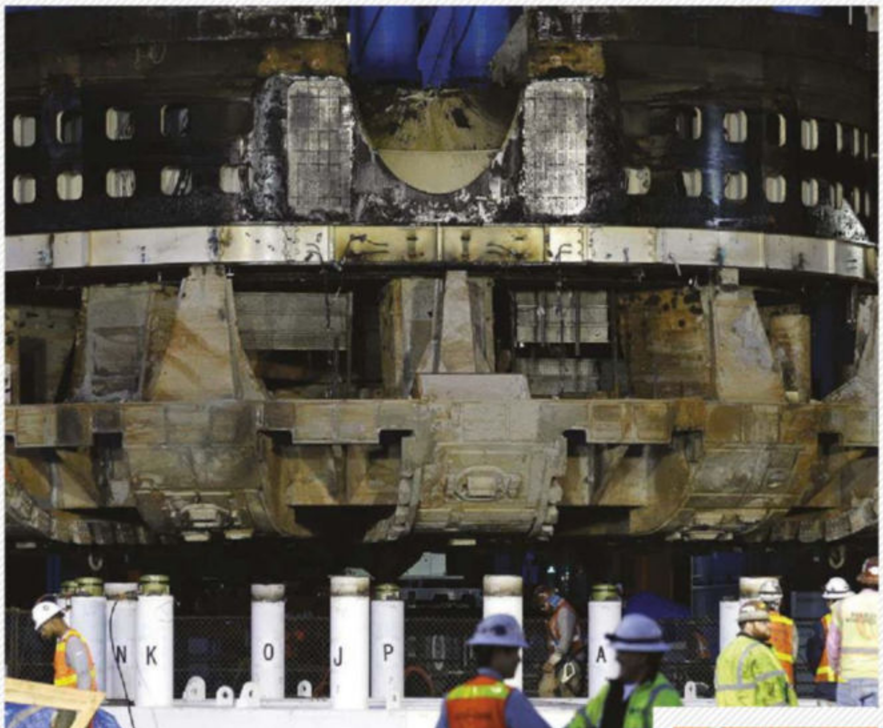


It's fine if a minor injury swells, but more serious ones can be problematic

A SWELLING IS A potentially useful response to injury or infection. It's caused by increased blood flow to the damaged area and an accumulation of white blood cells. These attack bacteria and remove dead cells before infection can set in. Even the pain associated with an inflamed injury is useful, because it encourages you to keep off it while it heals.

Our bodies have evolved a healing response that works tolerably well for minor cuts and bruises, but it can actually make a serious sprain or muscle tear worse because the increased fluid pressure cuts off the oxygen supply to the damaged tissues. The body actively regulates the inflammation response in an attempt to strike the right balance, but evolution isn't a perfect system. Our ancestors probably would have starved to death or been caught by predators before a major injury healed, so swelling would've been the least of their worries. **LV**

WHAT IS THIS?



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LAST MONTH'S PICTURE
Nobody managed to correctly guess a piece of broken eggshell!

Did you know?
Royal Observatory Greenwich's Burgess 'B' timepiece is the world's most accurate clock with a pendulum

MICHAEL VALENTINE, PLYMOUTH

For how long can a photon of light exist?

A IF, AS MOST physicists believe, these carriers of electromagnetic energy have no mass, they can't decay into anything else and so should last forever. It is theoretically possible they have a very tiny mass, but measurements suggest this is so low that photons have lifespans far longer than the current age of the Universe. **RM**

The lifespan of a photon is just a little longer than the film *Lawrence Of Arabia*...

ELLA CARR, FOLKESTONE

What is the biggest known star?

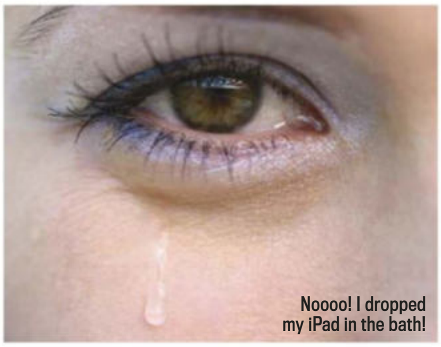
A ASTRONOMERS CANNOT BE absolutely sure which of the known stars are the biggest or most massive. The largest known star by radius is generally accepted as UY Scuti, which is a red hypergiant star about 9,500 light-years from Earth. Its radius is probably 1,708 times the Sun's (over a billion kilometres). The most massive star is probably RMC 136a1, a Wolf-Rayet star about 165,000 light-years from Earth. It is believed the mass of RMC 136a1 is about 256 times the Sun's mass. **AG**

UY Scuti: still not as big as Simon Cowell's ego

WORAWUT KHUNSIN, LONDON

Why do we cry when we're in pain?

WHEN YOU WERE a helpless infant, crying was a distress signal to encourage your parents to make things better again. In adulthood, most wild animals suppress these signals because they don't want to announce their vulnerability to predators, or rivals of their own species. To some extent, this instinct persists with humans as well, which could be one reason why men tend to cry less than women. But compared to most mammals, we are a highly social species. However much it hurts your pride, crying in pain summons help and warns people of danger. Both of which are useful evolutionary traits. **LV**



Noooo! I dropped my iPad in the bath!

London-based artist Stephen Wiltshire draws accurate cityscapes from memory

CHERYL HASTE, BIRMINGHAM

Is eidetic memory genetic or learnt?

EIDETIC MEMORY IN adults is very rare and thought to be inherited. Although sometimes referred to as 'photographic memory', this term is inaccurate because human brains are not like cameras and eidetic images are not really like photographs. Even so, when eideticers are briefly shown an unfamiliar picture they report 'seeing' a detailed mental image and can recall such tiny details as the number of windows in a street or petals in a flower. Also their eyes move as though they are scanning an image. Oddly, this extraordinary ability is not correlated with other memory skills nor with IQ. Between 2 and 10 per cent of young children experience eidetic imagery, but it tends to fade from about the age of six as they learn more efficient ways of dealing with information and develop verbal and autobiographical memory.

There are many claims, but no good evidence, that eidetic memory can be trained or taught. **SB**

ALEX ROUND, LONDON

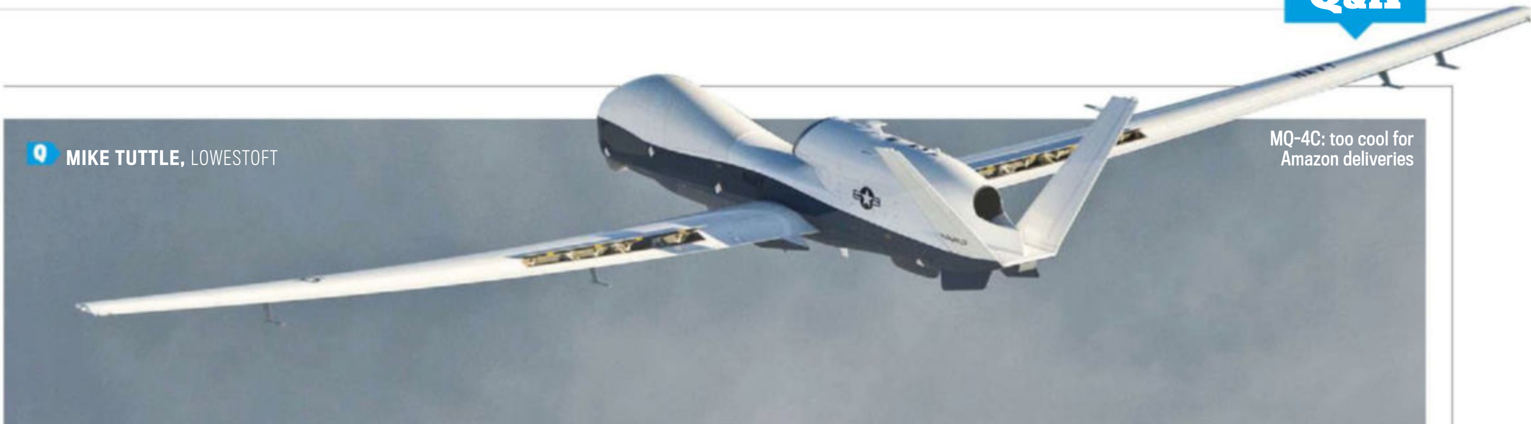
Why are thunderstorms more common in the summer?

THE SCIENCE OF how thunderstorms are triggered is still somewhat mysterious. Thunderstorms require the formation of clouds, inside which regions of positive and negative electric charges can accumulate. These lead to voltage differences so big – around 400,000V per metre – that electrons are stripped off the molecules within the cloud, forming violent electric flows we see as lightning.

Thunderstorms are more common during summer because the necessary conditions occur most readily when there's plenty of heat. Heat triggers convection, in which air becomes hotter, less dense and rises up from the surface. Plus, air holds most moisture when it's warm. While the processes that form the electric charges are not fully understood, it's believed to involve the interaction of violently rising moist air and ice crystals at high altitude.

In the UK, suitable conditions occur on only around half a dozen days during the summer. **RM**

PHOTO: ISTOCK X2, BARCROFT MEDIA, GETTY X2, US NAVY



MQ-4C: too cool for Amazon deliveries

Q **MIKE TUTTLE,** LOWESTOFT

What is the world's most sophisticated drone capable of?

A SOME OF THE most sophisticated Unmanned Aerial Vehicles are to be found in the military. About a year ago, details emerged of the US Air Force's secret autonomous aircraft, the RQ-180. Its main purpose is for reconnaissance in hostile airspace where its stealth design evades enemy radar. It has a massive 40-metre wingspan, which is 10 metres greater than a Boeing 737. This drone can fly continuously for 24 hours with a range of up to 2,500km. Its sensing and imaging equipment is based on radar and it is thought to have infrared cameras too.

Another highly advanced drone is the MQ-4C Triton. This is also a surveillance aircraft and the US Navy is developing it as an aerial platform for coordinating reconnaissance across huge swathes of ocean. Its radar can survey an area almost the size of Brazil in one go. This is thanks to the craft's 18km cruising altitude, which also keeps it safely out of reach of most anti-aircraft missiles. It even has de-icing and lightning protection tech. **GM**

Q **ANNETTE HUNSLEY,** MANCHESTER

How much does a parent's behaviour influence a child's?

Dressing like your kids is NEVER cool, no matter how tough you look

A A LOT. BUT parental influence is only one factor and it interacts in complex ways with genes and the wider culture of school, the media and other children. Some new parents believe they can mould their children as they wish and then have a rude awakening when they discover the child's inherited potential takes them in totally different directions. At the other extreme, some think they can get away with poor behaviour and dreadful parenting techniques. One important factor is how the parents behave with each other and whether the whole family functions well. Children do better in stable families where their parents are not often arguing or being unkind to each other. But all these effects are complicated by the fact that children can influence their parents too. Plus, the same parental behaviour may have larger, smaller or completely different effects on children with different temperaments. So although we can be sure that parental behaviour is important, we cannot easily disentangle it from all the other inter-related effects. **SB**

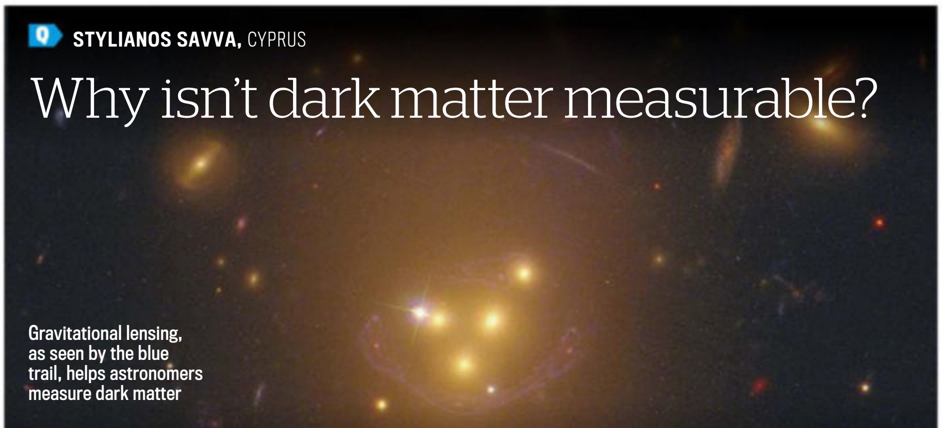
Q **HARRY GRIFFITHS,** TODMORDEN

How do fans make you feel cooler?

A AS LONG AS the air blowing past your face is cooler than your skin, some heat will transfer to the air molecules. The fan ensures the air molecules are moved out of the way before they have a chance to reach the same temperature as your face, and replaces them with other molecules that haven't been warmed yet. Similarly, sweating transfers some heat to the evaporated water molecules, and the fan prevents a humid layer from building up next to your skin that would slow down the rate of evaporation. **LV**

STYLIANOS SAVVA, CYPRUS

Why isn't dark matter measurable?



Gravitational lensing, as seen by the blue trail, helps astronomers measure dark matter

DARK MATTER IS measurable, it is just not visible. It is invisible because it is 'dark'. Astronomers infer the presence of dark matter because it explains how galaxies manage to hold themselves together, how gravitational lenses work and the observed temperature distribution of hot gas seen in galaxy clusters. The conclusion is that over 80 per cent of the mass of the Universe is in a form we simply can't see. Yet, despite its ubiquity, astronomers have no real idea what constitutes dark matter. It may include subatomic particles such as heavy neutrinos or other hypothetical particles like axions. Some of it may be locked up in objects that simply elude detection. Currently, astronomers believe most dark matter consists of new elementary particles called weakly-interacting massive particles (WIMPs), which apparently do not interact with electromagnetic radiation or atoms. They are therefore invisible to conventional means of detection. **AG**

ALAN THOMAS, SHEPPERTON

Is it safer to face backwards in a plane?

YES. IN THE event of a hard landing or minor crash, a rear-facing seat spreads the deceleration forces better across the body. A US Air Force study in 1957 found that passengers were seven times more likely to survive a crash if they sat facing backwards. But rear-facing seats have different stresses and would need to be made stronger and heavier, which would have an impact on aircraft efficiency. **LV**

First class, eh? Bet they're crying on the inside...

CECILIA CHUA, SINGAPORE

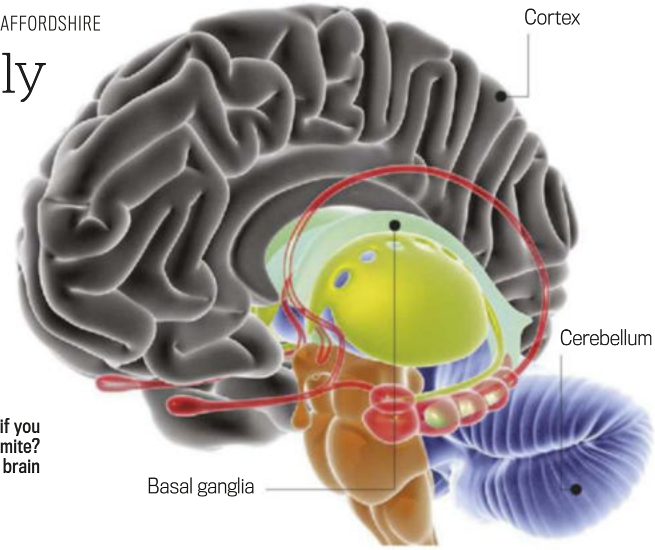
How accurate are fitness trackers?

FITNESS TRACKERS WORK by using accelerometers worn on your wrist, waistband or shoe to count your strides and convert that to an approximate measure of the distance travelled and the calories burned. Some also include altimeters, so they can give you extra credit for climbing stairs and hills. A 2014 study at Iowa State University compared them to more sophisticated laboratory equipment and found that most fitness trackers have error margins of between 10 and 20 per cent. Over a period of a week, that error adds up to about one day's worth of exercise. **LV**

Just *wearing* it doesn't make you fit, no matter how many you own

CONSTANCE HUTCHINGS, STAFFORDSHIRE

Is there really a fine line between love and hate?



Can't decide if you love or hate Marmite? Blame your brain

IN ONE SENSE, yes. When people see photographs of someone they love or someone they hate, two of the same brain structures are activated. The putamen, in the basal ganglia, is linked with contempt and disgust as well as choosing actions – obviously critical in both loving and hateful relationships. The insula, deep down in the cortex and involved in self-awareness and emotional processing, is also activated but there's a big difference: in romantic love, but not in hate, large parts of the cortex are deactivated. Perhaps rational judgment is needed for planning revenge or punishment, whereas romantic love makes us less rational about the perfect person we have fallen for. **SB**

NEXT MONTH Over 20 more of your questions answered

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PHOTO: DURHAM UNIVERSITY, GETTY, PRESS ASSOCIATION

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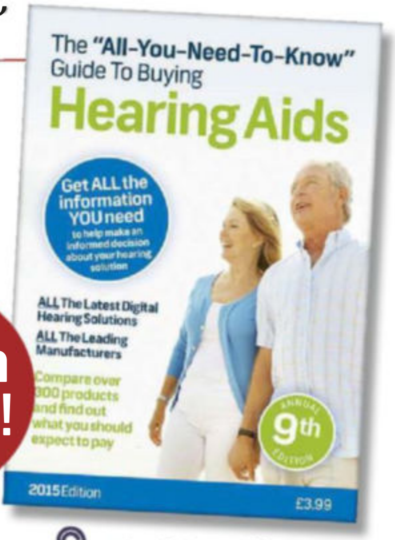

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THE FUTURE OF GADGETS

TECHHUB

EDITED BY **DANIEL BENNETT**

THIS MONTH

APPLIANCES OF SCIENCE
Crumb collectors, lazy shopping and more
p83

ULTIMATE TEST
Jetting off on your hols? Grab these stress-saving gadgets
p84

ON THE HORIZON

TESLA POWERWALL

The battery that could transform our energy use

BATTERIES ARE awful. For a start, they're always running out. I can't remember the last time my phone didn't need a charge at the end of the day. That's not to say batteries haven't improved over the years. They have. The trouble is they've only evolved just enough to cope with our increasingly energy-hungry gadgets.

Clearly, the small inconvenience of having to charge my phone every night isn't the biggest problem the world is facing right now. But there is a conundrum on the horizon, and batteries will need to take a massive leap in order to solve it.

More and more homes and businesses are starting to wean themselves off fossil fuels, either through green energy suppliers or by installing solar panels on their roofs or windmills in their gardens. Thanks in part to a subsidy from the government, there were 650,000 residential and commercial solar installations in the UK at the end of 2014, powering the equivalent of 1.5 million houses. That figure is

Tesla Powerwall and a Tesla car compete in the 'Who's Shiniest' competition

expected to grow again this year.

The trouble with renewable energy is its reliability. For example, solar power is only good until dusk, while wind power relies on the weather. This is where Elon Musk, the creator of PayPal, SpaceX and Tesla wants his new battery to step in.

The device, called the Tesla Powerwall, would be mounted in your home. It would soak up all the excess power generated by your solar panels, waiting to feed it back into the home during the night. Musk says his battery could store enough energy to power your home for an entire day. Indeed, the entire launch event was powered just by his batteries.

It's not just technology for the green-fingered either. The unit can be installed into any home and programmed to recharge during your energy providers' off-peak hours, stuffing itself with low-cost electricity before regurgitating it back into the house during peak hours, slashing your bills over the long-term.

At first, running your entire home off batteries might seem complete illogical. But Musk is probably the only person in the whole world who could pull this feat off. For a start, his battery-powered Tesla Model S has three times the range of most other electric cars. Musk is using the knowhow gained in developing the best electric car in the world to try and build the best battery in the world. Right now, his company is busily building the biggest battery factory on the planet, named Gigafactory 1. Forecasts suggest that the factory will reduce Tesla battery costs by about 30 per cent.

The Tesla Powerwall will only be available in the US for now and costs $3,000 dollars for a 7kW battery and $3,500 for a larger 10kW system. Incredibly, the batteries are already sold out in the US until 2016. If Musk's plans are successful, he won't just be worrying the motoring industry, he'll have the energy companies panicking too.

DANIEL BENNETT is the reviews editor at *BBC Focus Magazine*

TECHOMETER

WHAT'S HOT

DRONE DELIVERY

When Amazon announced deliveries by drone, most thought it was just a stunt. But now, the company has submitted a patent for a system where a drone tracks the location of the person to whom it's delivering using data from their smartphone. The drones would also be able to talk to one another.

WHAT'S NOT

3D TV

After five years, Sky is scrapping its 3D channel. Despite investing in original programming, including several David Attenborough documentaries, the channel failed to gain any real traction with viewers. It seems now that there are fewer and fewer options for getting 3D content, but keen viewers will still be able to access the channel through Sky's on-demand service.

READER POLL

Do you watch any 3D content?

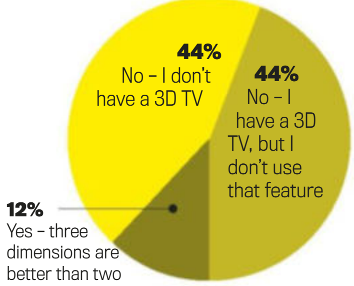


PHOTO: AMAZON, GETTY, MARC HALL/NC STATE UNIVERSITY

THE NEXT BIG THING

THE NANOCOMPUTERS ARE COMING

IT HAS BEEN 50 years since Intel's Gordon Moore noticed that the power of computer chips was doubling about every year. He coined this phenomenon 'Moore's Law'. Since then, we've seen enormous changes in the way the world works and in the types of technology that underpin our daily lives.

The assumption that we can rely on more computing power at less cost – and with reduced energy consumption – underpins many anticipated changes in the world, such as smart cities, self-driving cars and wearable computers.

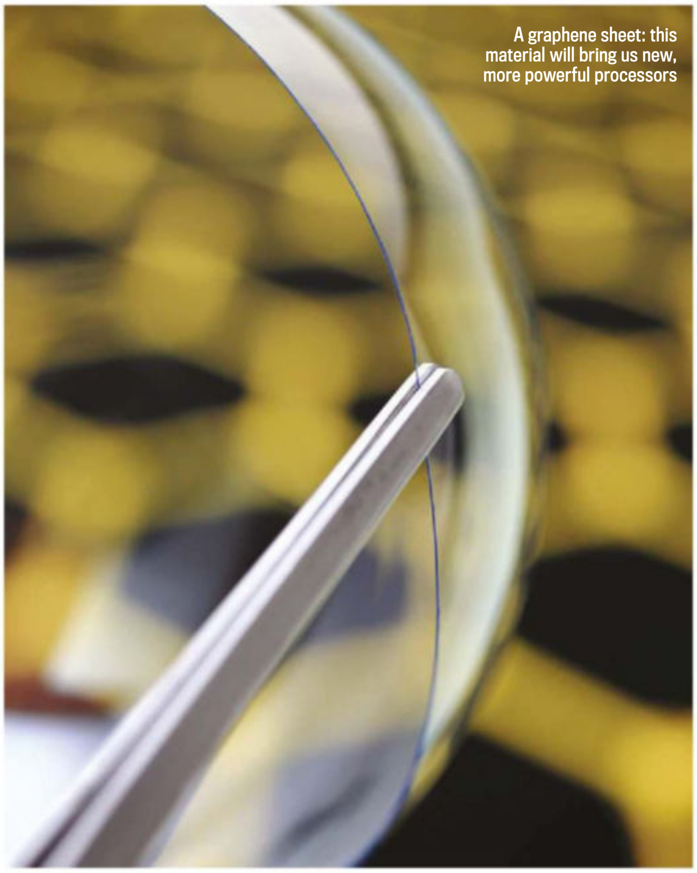
Yet we can't rely on existing materials to deliver the sort of performance we will need, so we need to look elsewhere. The most promising developments are coming from nanotechnology – the design, manufacture and use of materials at the scale of 1-100 nanometres (one nanometre is a billionth of a metre) to build smart fabrics, intelligent roads and new forms of computer.

Nanoparticles are already out there, in things like sunscreen and scratch-resistant coatings for glasses. For me, the exciting materials are those that can be used in computers, like graphene.

Graphene is a recently-discovered form of carbon. It looks like it can support a new generation of powerful processors that run cool and fast, letting us extend the lifetime of Moore's law by moving away from silicon-based computing.

And as that happens we can expect new possibilities to emerge, just as the move from valves to transistors transformed the sorts of electronic devices we could imagine. For example, we might have smart fabrics with sensors built in, keeping track of pulse, temperature and perspiration, and they'll also be responsive to the environment or your activity.

But the real impact will come when we know how to build these new types of device at scale, and to deploy them in ways we can depend on. I once asked Maurice Wilkes, who in 1949 led the team that built EDSAC, one of the world's earliest computers, what most surprised him about modern processors.


A graphene sheet: this material will bring us new, more powerful processors

He said it was their reliability. EDSAC used 3,000 valves that were prone to burning out, so the machine would have to be repaired every few hours. In contrast, today's processors run trillions of instructions without error. For example, the laptop I'm currently using hasn't been rebooted for 15 days.

Before long it looks like we'll come to depend on these strange nanomaterials for computing. Their impact may not always be positive, and it will definitely not be easily predictable. There are already concerns over the impact of some nanomaterials on the environment and on our bodies. But the new nanomaterials are coming, whether we prepare or not.

BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service

FROM THE LAB

The boots that put a spring in your step...

WHAT IS IT?

These boots are more like an exoskeleton than shoes and have been developed at the University of North Carolina. They strap around your shins and calves, mimicking the muscles and tendons. They make walking 7 per cent easier – equivalent to taking 4.5kg off your back.

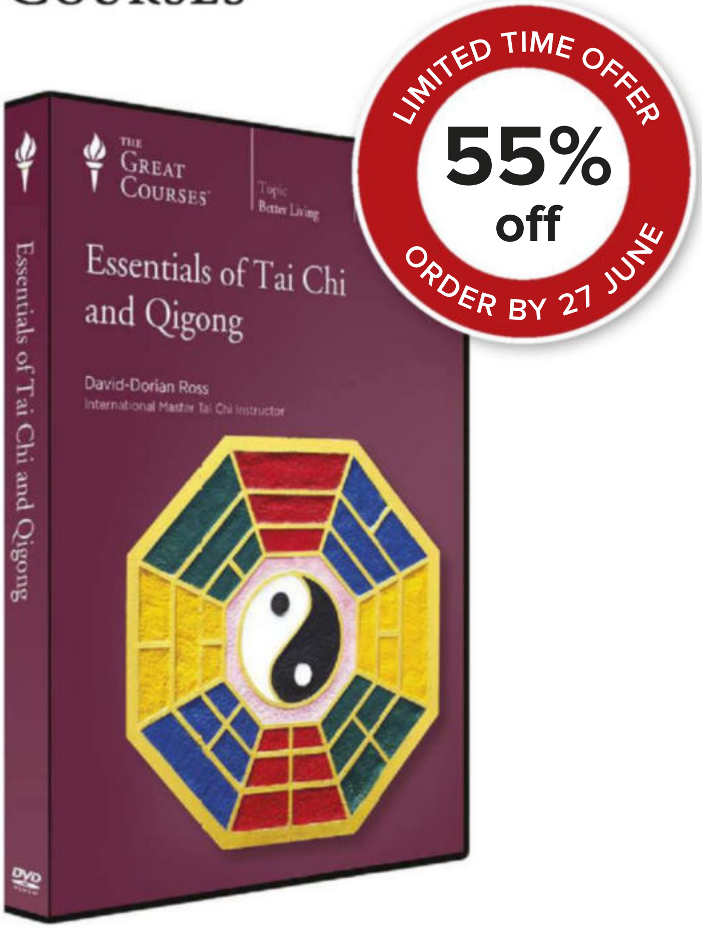
HOW DO THEY WORK?

The boots are unpowered, instead relying on simple mechanics. Inside, there's a ratchet that catches the spring and keeps it taut when your foot is flat on the ground. With the spring fully extended it holds elastic energy. When the walker lifts their foot the ratchet releases the spring and its stored energy, literally putting a spring in every step.

WHEN CAN I GET ONE?

The boots' engineers are working on a prototype that could help those with injuries or the elderly. According to one of the authors, we might see the boots "someday soon".

The exoskeleton helps people walk more efficiently



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9. The Second Pillar—Push Hands for Two
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1

2

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4

5

6

APPLIANCES OF SCIENCE

1 SUNFLOWER POWER

This Smartflower is an 'all-in-one' solar system – by which its creators mean that, once it's delivered, all you need to do is wire it into your mains to get up and running. From there, its petals open at dawn, rotate to follow the Sun and clean themselves at night. It'll even fold away to protect the panels on windy days. Don't be fooled by the scale of our picture, though: you'll need at least $25m^2$ of space to set it up.

Smartflower POP
Price TBC, smartflower.com

2 CRUMB COLLECTOR

Kitchen bins were the last thing we thought needed the 'smart' treatment. How wrong we were! Bruno the bin is fitted with a small vacuum cleaner at its base, and when a sensor spots your broom brushing against the bin's base, it sucks up all the dirt nearby directly into its rubbish bag. Bruno will even tell you when you're running low on bags, and text you when it's time to take the bins out.

Bruno Smartcan
Price TBC, brunosmartcan.com

3 SKY HIGH

From landing on the White House lawn to flying over volcanoes, DJI Phantoms are the drones in the news. The new Phantom 3 focuses on ease of flying. There's now an ultrasound sensor in the base that measures altitude, allowing it to hover effortlessly, and a Launch button that sends the phantom leaping instantly into the air. Phantoms also now come with the option to film in 4K (four times HD resolution).

DJI Phantom
From £899, dji.com

4 ONE-STOP SHOP

Death and taxes aren't the only constants in life. There's also buying loo roll, toothpaste, washing powder and other sundries. The Dash button wants to free you from this drudgery. You simply order a button for one of your favourite products (bourbon biscuits, say), and each time you hit it, Amazon will deliver them to your door. Actually, for your waistline's sake it's probably best not to make a biscuit button…

Amazon Dash Button
Free, amazon.com

5 CRYSTAL CLEAR

4K TV is four times sharper than Full HD, or 1080p. There's no rush to upgrade your TV just yet, as no broadcasters are currently offering programmes at this quality. But with Netflix already committed to streaming 4K shows and Sky promising a 4K box later in the year, it might be time to invest soon. Luckily, Vizio is here to spare your wallet: it's the first TV maker to offer 4K sets for under £1,000.

Vizio P Series
From $599 (£394), vizio.com

6 LASER SHOW

Everything is better with lasers, and that includes projectors. Normally projectors suffer when they're shrunk: the light bulbs are too small, and the resulting picture is soft and difficult to see. By using lasers instead, this projector has been shrunk to the size of an iPhone 6 without scrimping on the image quality. Plus, unlike traditional projectors, the laser system won't need focusing and can work at short range.

Celluon Picopro
$349 (£230), celluon.com

TRAVEL

Whether you're jetting away or planning a staycation, here's our pick of the top tech that can make your life better this summer...

PHOTO: THESECRETSTUDIO.NET

TRANSFORMERS

PANASONIC LUMIX DMC GF7

These days, taking a good selfie is as much a part of going on holiday as getting sunburn, fighting over sunloungers and getting sand in your shoes. To help you capture the perfect selfie, this camera's display flips 180°. In this mode, the device's AI takes a photo three seconds after it sees you waving. Similarly, if it sees two or more faces smushed together it'll take a pic. And for its party trick, if you pair it with a smartphone and activate Jump Snap mode, it will use the phone's accelerometers to calculate when your jump will peak and take a picture at the perfect moment. **£399, panasonic.com**

OVERBOARD WATERPROOF CAMERA CASE

This bag won't just protect your camera from water, sand, dust and mud, it'll also let you take pictures underwater. The camera case can safely venture six metres below the waves and will float back up to the surface if you accidentally drop it in the briny. **£19.99, overboard.com**

POLAROID ZIP INSTANT

Spare your pictures the fate of living permanently on your smartphone with this minuscule printer. No bigger than a Nintendo DS, it'll connect to your phone or tablet via NFC and Bluetooth to print your photographs, smudge-free, on 2 x 3 inch (5.08 x 7.6cm) sticky-backed photo paper in under 60 seconds. **£109.99, polaroid.com**

COBRA JUMPACK

Taking a road trip this summer? This mobile battery charger can give your phone and your car a second lease of life. Plug the USB into your phone and the 7500mAh charger will give it another day's worth of charge several times over. But if your car's battery gives out, you can use the cables included to give your vehicle a jump start. **£79.99, cobra.com**

EYEFI CARD

Don't get strangled by cables. The Eyefi memory card has a built-in Wi-Fi chip that will send your photos to your tablet, PC, Mac or smartphone when both are connected to a trusted Wi-Fi network. Best of all, it'll also send those pics to the cloud, if you have a subscription, so that all your photos are immediately backed up. **£33.33, en.eyefi.com**

BRAVEN BRV-PRO ▶

If you're taking a speaker with you on holiday or to a festival, you'll want one that can handle anything. Built out of aircraft-grade aluminium, the BRV-PRO will roll with the punches, survive a dunk in water, and all the dust, mud or sand you can throw at it.

£129.99, braven.com

NETATMO JUNE ▼

Keep tabs on the Sun with one of the best-looking wearables going. The June combines local weather reports and data from its UV sensor to tell you what factor sun cream you should be wearing and how often you'll need to reapply it to avoid any lasting damage.

€129 (£95.40), netatmo.com

STEELSERIES STRATUS ▼

Keep the kids occupied with this videogame remote for your iPad. It makes longer, more engrossing games like *FFX* or *Need For Speed* much more engrossing – meaning that your sanity is more likely to be intact by the time you reach your destination.

£59.99, steelseries.com

LOTUS GRILL ▲

Here's a barbecue that's purpose-built for the British summer. It uses a battery-powered fan to stoke just a handful of charcoal, providing enough heat to cook your burgers in the park. Best of all, the fat from your food can't reach the coals, so there's no smoke – meaning you can take it under cover when the rain clouds inevitably roll in.

£139, cuckooland.com

SMART KEY ▲

Never lose your keys on holiday! Pop them on this key ring and hook it up to your mobile via Bluetooth. If the phone loses the connection, it will start to sing. If you miss the alert, your phone logs the last GPS location where it had a connection and shows you how to get there via Google Maps.

£39.95, elgato.com

OLLOCLIP ▲

These interchangeable lenses for your smartphone will give you one more reason to just leave your camera at home. Each Olloclip kit comes with a selection of four different lenses that slide over your smartphone's camera: a fisheye, a wide-angle and two macro lenses.

£69.99, olloclip.com

◀ PARROT ZIKS 2.0

Ziks are the most versatile, noise-cancelling headphones money can buy. As well as drowning out plane engines, Ziks will customise audio output for each track through its phone app. All the controls are on the right can, so you don't have to fumble around for your phone to change the track.

£299, parrot.com

PHOTO: THESECRETSTUDIO.NET

AND FOR YOUR NEXT HOLIDAY...

5 GADGETS YOU'LL BE ABLE TO BUY NEXT YEAR

BLUESMART ▶

Meet the ultimate suitcase. Before you fly, its built-in digital scale will tell your smartphone how much your luggage weighs, and when you're packed and ready to go you can lock the suitcase from your smartphone. It also comes with a built-in battery charger should your phone run out of juice. As well as logging your trip, it'll ping you its GPS location if you move out of range of the bag. If it's been lost, Bluesmart will track it down and ask if you want your bag brought to you by an Uber hire car. It can't arrive soon enough.

Bluesmart.com

◀ GOJI SMART LOCK

Never leave a spare set of keys under the plant pot again. This smart lock lets you open your door from anywhere in the world, as long as your smartphone or tablet has an internet connection. Alternatively, you can give your friends and family access to your house for a couple of weeks. And if someone visits, Goji will take a picture and send it to you.

Gojiaccess.com

PETCHATZ ▶

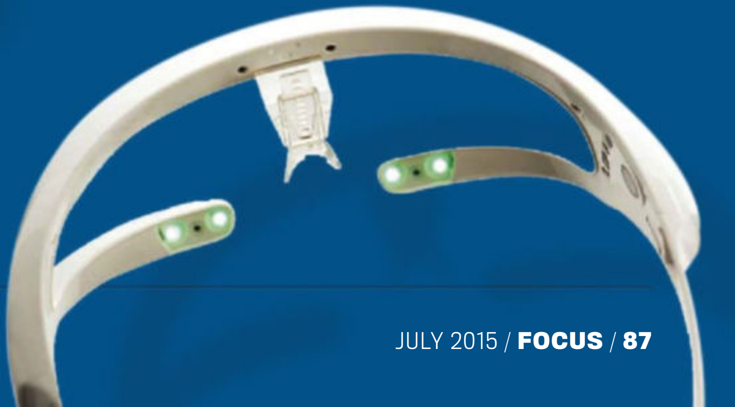
If you can't bear to be away from Fido or Snuggles, there will soon be a way to keep in touch. This videophone drops a treat when you call to lure your cat or dog to the camera. Once they're there you can have a good chat – or whatever it is you do with a cat on a videophone – and you can even instruct the device to dispense a soothing scent to reassure your furry friend.

Petchatz.com

◀ SAMSUNG GEAR VR

Cramped seats, terrible food and air-con that dries you to a husk – we've all sat on a long-haul flight counting the hours to touchdown. Well, this mobile virtual reality headset could transform your flight, letting you play games and watch movies from the comfort of your own virtual world, leaving reality (and the plane) far behind.

Samsung.com



RE-TIMER ▶

Jetlag is a killer, but now it might have met its match: the Re-timer. These specs shine a green UV-free light into your eyes that's proven to help rejig your circadian rhythms. The idea is that four days prior to your next long-haul flight, you could wear the Re-Timer to slowly shift your sleep patterns to match those of the country you're visiting.

Re-timer.com

THE ROBOTIC RACE TO THE MOON

Rovers could be roaming the lunar soil this year, says **Rob Banino**, but who's in pole position?

THE FIRST SPACE race began back in 1955, when eminent Russian physicist Leonid Sedov revealed the USSR's intention to send a probe into space four days after the US announced plans to launch a satellite. Sixty years later and we are approaching the closing stages of another space race: the Google Lunar XPRIZE (GLXP).

The finish line is the same, the Moon, but the competitors are different. Rather than nations with competing ideologies, they're private companies seeking to commercialise space. And all they have to do to win the $20m (£13m) grand prize is be the first to have a non-government-funded vehicle drive on the Moon's surface.

"The GLXP is asking teams to accomplish a feat that has never been achieved: land a private craft on the lunar surface, then have it travel at least 500 metres and transmit high-definition video back to Earth," says GLXP's president Robert Weiss. And they have until 31 December 2016 to do it.

More than 30 teams signed up to GLXP when it launched in 2007. Only 18 are still in the running, and of these, five are clear frontrunners. In January this year these teams shared Milestone Prize money totalling $5m (£3.2m) for demonstrating viable technology across three categories: landing, mobility and imaging.

America's Astrobotic team was the only one to win prizes in each of the

PART-TIME SCIENTISTS

BERLIN, GERMANY

MILESTONE PRIZE MOBILITY
SIZE 90 x 75 x 60cm
WEIGHT 40kg

This team is comprised of scientists from all over Europe collaborating via the internet. The Part-Time Scientists team is building a four-wheeled, solar-powered rover called Asimov, which they tested on Tenerife's Mount Tiede volcano in December 2014 due to its similarity to the lunar surface. Their aim is to have Asimov travel to the Apollo 17 landing site and take pictures.

MONEY AWARDED $500,000

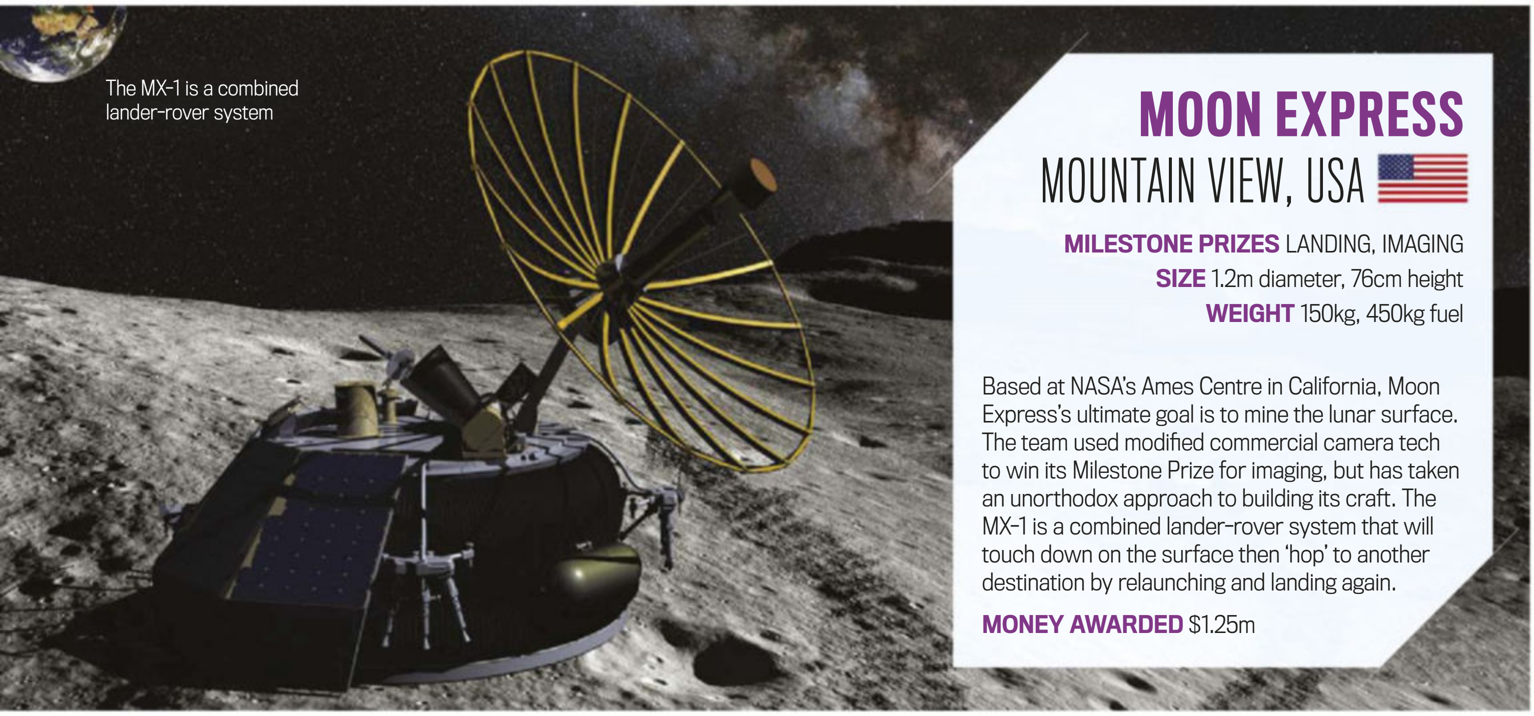
categories, thanks to the progress made with its Griffin lander and Andy rover. Astrobotic proposes to carry at least four other competitor rovers to the Moon in Griffin, which is set to launch aboard a SpaceX Falcon 9 rocket in the second half of next year.

The sole Japanese entry, Hakuto, is signed up as Astrobotic's first passenger. Hakuto won a $500,000 mobility Milestone Prize for its paired rovers Moonraker and Tetris.

"We are planning to explore a hole on the Moon that's thought to be a lava tube," says Hakuto's Kyoko Yonezawa. "A lava tube would be a perfect place to build a lunar base, since it would be protected by a thick layer of rock from intense radiation and extreme temperatures. Tetris, connected by a tether to Moonraker, will be lowered into the hole to explore the lava tube."

The potential fortunes to be made from payload delivery systems, colonisation and lunar mining are what all the GLXP competitors ultimately aspire to, but the first challenge they have to overcome is funding. Although the prize money for the winner and runners-up totals $30m (£19.7m), it's just a drop in the ocean compared to how much is needed to turn these projects into viable businesses. That's the real challenge behind the GLXP – to make lunar exploration affordable for organisations other than government agencies, so we don't have to wait another 45 years before our next visit to the Moon.

PHOTO: XPRIZE PRESS OFFICE



The MX-1 is a combined lander-rover system

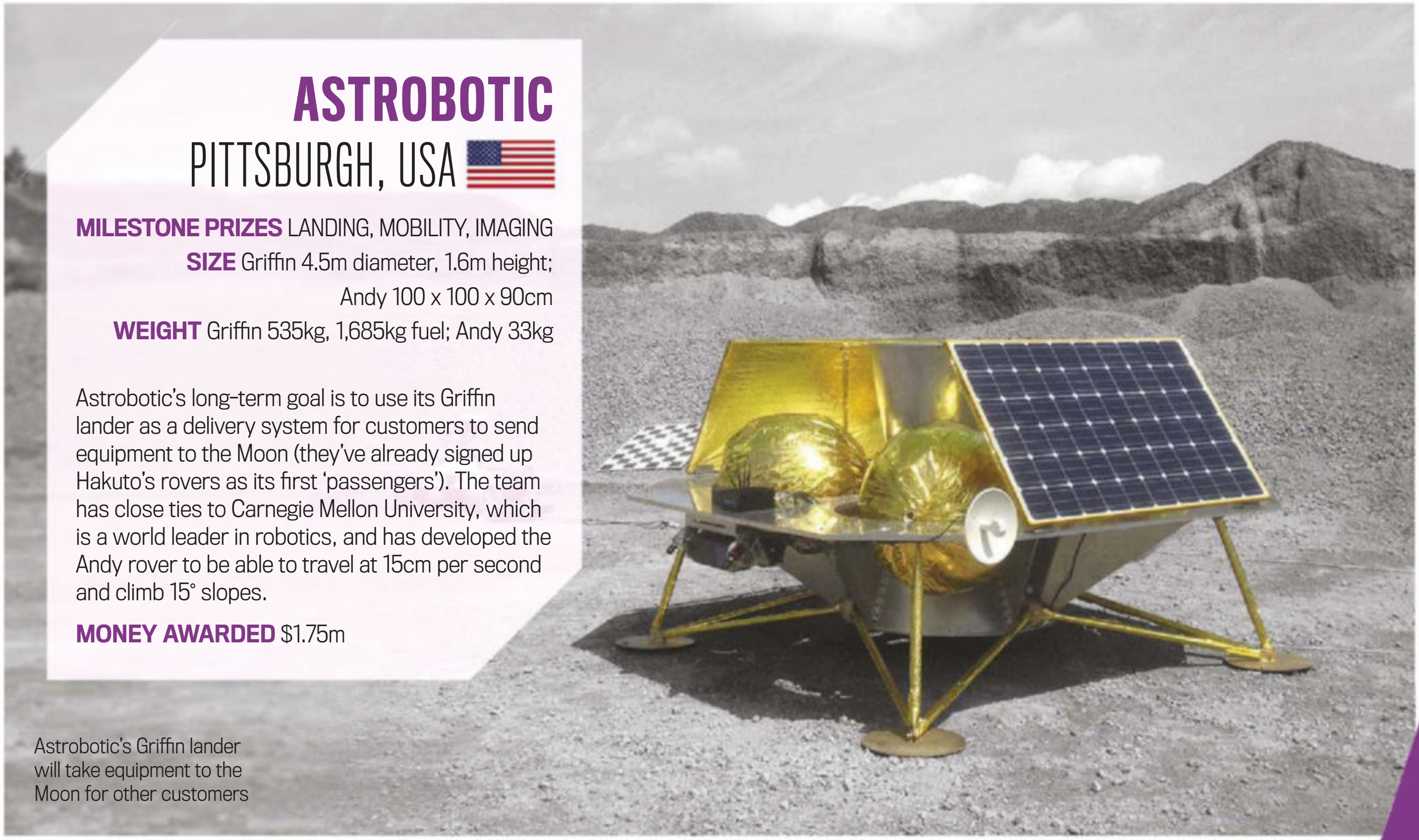
MOON EXPRESS

MOUNTAIN VIEW, USA 🇺🇸

MILESTONE PRIZES LANDING, IMAGING
SIZE 1.2m diameter, 76cm height
WEIGHT 150kg, 450kg fuel

Based at NASA's Ames Centre in California, Moon Express's ultimate goal is to mine the lunar surface. The team used modified commercial camera tech to win its Milestone Prize for imaging, but has taken an unorthodox approach to building its craft. The MX-1 is a combined lander-rover system that will touch down on the surface then 'hop' to another destination by relaunching and landing again.

MONEY AWARDED $1.25m



Astrobotic's Griffin lander will take equipment to the Moon for other customers

ASTROBOTIC

PITTSBURGH, USA 🇺🇸

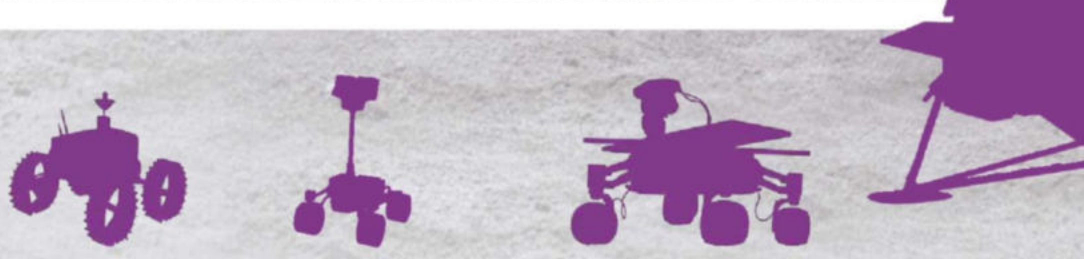
MILESTONE PRIZES LANDING, MOBILITY, IMAGING
SIZE Griffin 4.5m diameter, 1.6m height; Andy 100 x 100 x 90cm
WEIGHT Griffin 535kg, 1,685kg fuel; Andy 33kg

Astrobotic's long-term goal is to use its Griffin lander as a delivery system for customers to send equipment to the Moon (they've already signed up Hakuto's rovers as its first 'passengers'). The team has close ties to Carnegie Mellon University, which is a world leader in robotics, and has developed the Andy rover to be able to travel at 15cm per second and climb 15° slopes.

MONEY AWARDED $1.75m

ROBOTS TO SCALE

The XPRIZE competitors are packing some serious technology inside their Moon exploration systems. But how do they measure up to one another?



Hakuto Moonraker rover

Team Indus rover

Part-Time Scientists Asimov rover

PHOTO: XPRIZE PRESS OFFICE X4

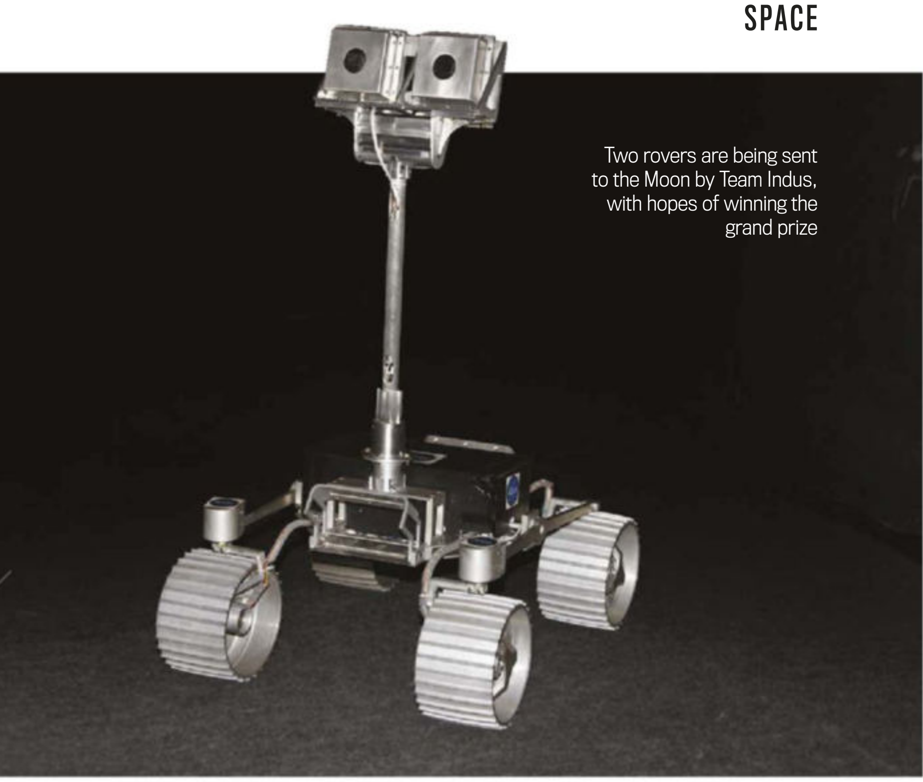
TEAM INDUS

NEW DELHI, INDIA

MILESTONE PRIZE LANDING
SIZE Rover 40 x 50 x 60cm
WEIGHT Rover 12kg

Team Indus plans to use a Polar Satellite Launch Vehicle rocket belonging to the India Space Research Organisation to take its HHK1 lander and two solar-powered rovers into space. One of the rovers is tasked with winning the $20m grand prize, but Team Indus is looking to set range and endurance records with its second vehicle.

MONEY AWARDED $1m



Two rovers are being sent to the Moon by Team Indus, with hopes of winning the grand prize

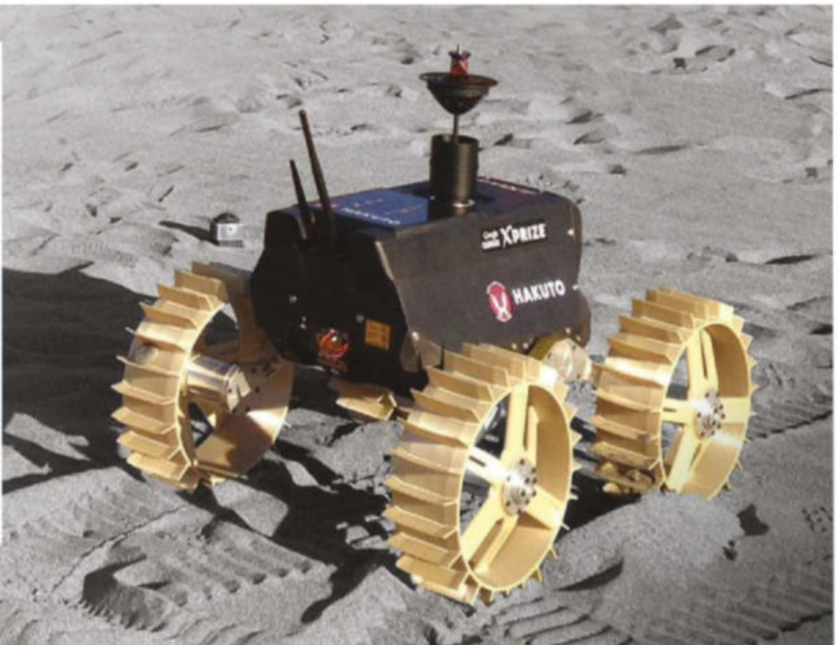
HAKUTO

TOKYO, JAPAN

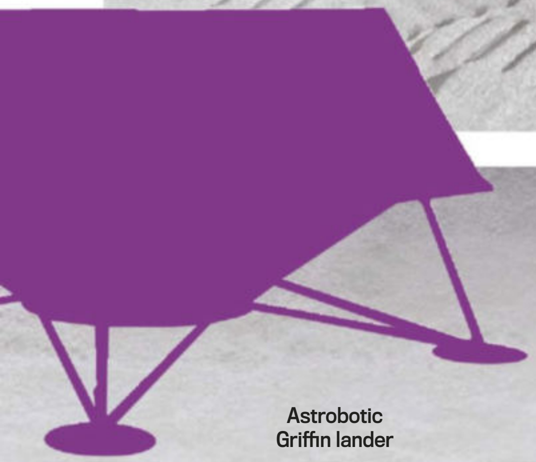
MILESTONE PRIZE MOBILITY
SIZE Moonraker 48 x 60 x 54cm; Tetris 27 x 54 x 21cm
WEIGHT Moonraker 8kg; Tetris 2kg

The word 'Hakuto' comes from a Japanese folktale and means white rabbit – hence the ears on the team's logo. The team, based at Tohoku University, is using Astrobotic's lander to carry its Moonraker and Tetris rovers to the Moon where it hopes to win the range prize by using Tetris, its smaller rover, to explore a lava tube beneath the lunar surface.

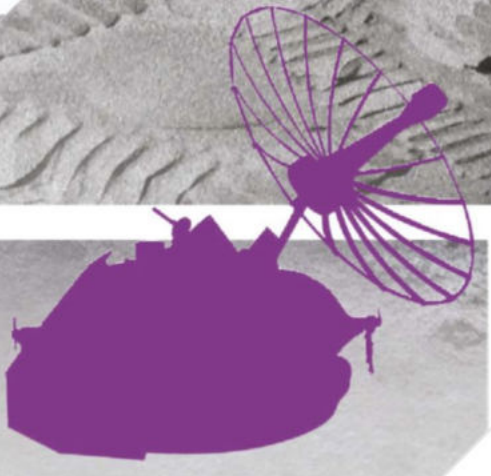
MONEY AWARDED $500,000



Moonraker, shown here, is the larger of the two rovers. It will lower the Tetris rover into lava tubes



Astrobotic Griffin lander



Moon Express MX-1 lander-rover

Find out more

Listen to *The Making Of The Moon* at **bbc.co.uk/programmes/b04mgxts**

ROB BANINO is a science and technology journalist. He also writes for our sister science title *BBC Sky At Night Magazine*

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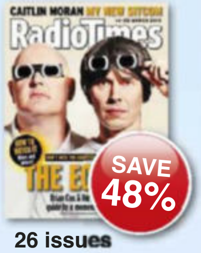

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PICK OF THE MONTH

CATCHING HISTORY'S CRIMINALS: The Forensics Story

BBC presenter Gabriel Weston takes a closer look at forensics

WHETHER IT'S VISITING murder scenes, analysing blood spatters or combing mutilated corpses for clues, the varied tasks of a forensic scientist are not for the faint-hearted. Now a new series on BBC Four takes an in-depth look at this most grisly of professions. Presented by surgeon and writer Gabriel Weston, the three-part series reveals how key cases in history have led to new breakthroughs in forensic science.

Take the case of Colin Pitchfork, for example. In 1988, the baker from Leicestershire became the first person ever to be convicted of a crime based on DNA fingerprinting evidence, with the new technique being used to prove beyond doubt that he had raped and murdered two teenage girls. DNA fingerprinting was developed by Prof Sir Alec Jeffreys at the University of Leicester, and it has revolutionised our ability to catch and convict criminals.

As well as historic cases, we're also brought bang up-to-date with current forensic techniques. One ongoing area of research is forensic entomology, which involves using insects to solve a crime.

"Martin Hall at London's Natural History Museum showed us how maggots can be used to date precisely when a murder has taken place," says Weston. "In the museum's garden, he has a series of suitcases with rotting pigs' heads in them. By putting the maggots through a tiny CT scanner, he's able to date how old they are, and so determine how long the body parts have been in the suitcase."

Perhaps most impressive of all, though, is the work of forensic geoscientists. "I walked around a muddy park in Glasgow, and then sent off one of the wellies to be analysed," says Weston. "From the mud on my boot, the scientist was able to locate where I'd been walking to within 100 square metres – that's out of some 75,000 square kilometres of Scotland."

In other words, thanks to scientific advances, criminals in the UK now have their work cut out. "I hope people will take away a sense of how good forensic science is in this country," she says. "This is not a place to commit a murder."

JAMES LLOYD

BBC FOUR *Catching History's Criminals* airs on BBC Four this summer. See radiotimes.com for more details

DON'T MISS!

The Big Picture

Kal Penn explores the brave new world of 'big data' and how scientists are adjusting to it **p94**

Dear Harry...

Commemorating the work of Henry Moseley, a brilliant British scientist who was killed in World War I, aged just 27 **p97**

Lovelace And Babbage

This steampunk comic collection explores the impact of these early computing pioneers **p98**

PHOTO: ISTOCK

WATCH

TV & ONLINE

WITH JAMES LLOYD

26 MAY

Impossible Engineering

National Geographic, 8pm

Greece's Rio-Antirrio Bridge

A 3KM-LONG bridge? A skyscraper that stretches 632m into the sky? An airport built on an artificial island? This new series explores the world's most jaw-dropping megastructures, revealing how engineers built incredible constructions such as Greece's Rio-Antirrio Bridge, China's Shanghai Tower and the Kansai International Airport in Japan.

FROM 7 JUNE

Inventions That Shook The World

Quest, 8pm

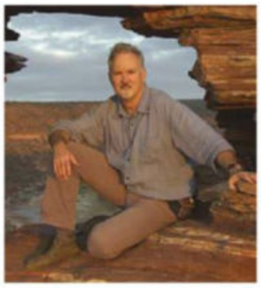
Parachutes evolved from this…

IF A TIME-travelling Victorian were to visit the modern world, they'd be awfully confused. This 10-part series takes a decade-by-decade look at the inventions that defined the 20th Century and transformed our lives, whether for the good (the radio), the bad (the machine gun), or the just plain annoying (the parking meter).

13-14 JUNE

Australia Weekend

Eden, all day



Travel through time and space with Richard Smith

EDEN DEDICATES A weekend to our pals Down Under. Highlights include *Australia: A Time Traveller's Guide*, in which Richard Smith (pictured) takes us from the birth of the Solar System through to present day Oz, and *Kangaroo Dundee* – a heartwarming documentary about a man whose macho appearance belies his fondness for rescuing orphaned joeys. Bonzer!

JAMES LLOYD is the editorial assistant at *BBC Focus Magazine*

EDITOR'S CHOICE

Kal Penn digs through data to visualise it in new ways

31 MAY

The Big Picture With Kal Penn

National Geographic Channel, 6pm

WE'VE GOT INFORMATION coming out of our ears. Love it or loathe it, the digital age means that we're able to store, share and download more data than ever before.

But what are we going to do with it all? In this new series, actor Kal Penn (of *House* and *Harold & Kumar* fame) helps us make sense of the data that surrounds us, finding connections and visualising the data in useful new ways.

He reveals how a spot of number-crunching and historical digging can lead to some unexpected rewards: just ask the man who discovered $3m worth of baseball cards in his aunt's attic. And then there's the mountain of stats created by sportsmen and women around the world, which Kal uses to create the ultimate fantasy sports team.

We also meet some of the scientists who are putting their data-processing abilities to good use, from the Texan meteorologist who's tackling devastating drought to the virologists fighting the world's most dangerous creature. No, not Justin Bieber – the mosquito.

PHOTO: NATIONAL GEOGRAPHIC CHANNEL X2, UKTV, DISCOVERY NETWORK

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LISTEN

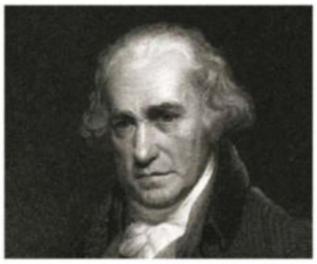
BBC RADIO PROGRAMMES

WITH JAMES LLOYD

JUNE

Science Stories

BBC Radio 4, dates TBC



James Watt was a steamy fellow

IN THIS NEW series, a selection of today's best-known science writers uncover some of the greatest untold stories. Find out how the accidental discovery of a purple dye launched the modern pharmaceutical industry, and why James Watt's steam engine almost didn't get beyond his drawing board. Pub quiz fodder galore!

1 JUNE

Discovery: What The Songbird Said

BBC World Service, time TBC

COULD BIRDSONG PROVIDE new insights into speech? With recent research showing that baby birds pick up songs in much the same way as baby humans learn language, Angela Saini finds out whether our feathered friends might tell us something about the evolution of language.

2 JUNE

The Forum

BBC World Service, time TBC

IN THIS EPISODE of *The Forum*, Bridget Kendall looks at the science of bringing things back to life. Beth Shapiro asks whether we could – and should – clone a mammoth; Bill Smith explains how he's rebuilt the ill-fated Bluebird boat; and Jyotsna Kalavar talks about the challenges of reviving Sanskrit.

2 JUNE

Natural Histories

BBC Radio 4, 11am

WILDLIFE EXPERT BRETT Westwood presents a new weekly series exploring 25 species that have changed the way we see the world. Expect episodes on the big hitters of the animal kingdom, but also some oft-overlooked critters. We're looking forward to the one on the humble flea.

Fleas: bringers of plague

ONLINE

Digital Human

bbc.co.uk/programmes/b01n7094

WHAT CAN TECHNOLOGY tell us about ourselves and the world in which we live? Catch up with the latest series of Aleks Krotoski's programme. Topics up for discussion this time around include secrets, magic and seduction.

PHOTO: ISTOCK X2, PRESS ASSOCIATION, CORBIS, HOWARTH-LOOMES COLLECTION AT NATIONAL MUSEUMS SCOTLAND

TOUCH

SMARTPHONE & TABLET APPS

WITH KATE RUSSELL

iNaturalist

iOS 7.0 or later, iPhone/iPad/iPod Touch/Android 2.3.3 or later, iNaturalist LLC, free

IF YOU LIKE exploring the great outdoors and want to keep a record of what you find, *iNaturalist* is the perfect pocket companion. The app allows nature lovers to connect with one another, sharing observations and linking up with local projects and guides to really get the most out of the environment. By contributing your own observations you'll be helping build the crowd-sourced database for your area. There are some pretty interesting projects going on too, like a group of researchers in America who are using it to build a database of edible weeds.

Robots For iPad

iOS 8.0 or later, iPad, Institute of Electrical & Electronic Engineers Inc, free

ROBOTS HAVE BECOME a familiar part of most industrial processes, but it was actually Leonardo da Vinci who first conceptualised the idea when he sketched out a design for a mechanically automated suit of armour way back in the 15th Century. *Robots For iPad* contains a wealth of facts from some of the world's leading experts on the topic of robotics. You can explore over 150 different robots from 19 countries, with 360° images, video and audio guides and plenty of articles to read.

Universal Zoom: All About Sizes And Distances

iOS 7.0 or later, iPhone/iPad/iPod Touch, Gamify It, £2.99

WHAT WOULD IT be like to stand next to a sperm whale? Apart from feeling wet, you'd also feel pretty small – with *Universal Zoom* you can get a sense of just how tiny. The simple premise of this app – to show you how large or small things are in relation to each other – is made beautiful and elegant with a seamless interface and ambient sound track. As well as sliding up a universal scale from an electron to the observable Universe, you can explore and compare in categories such as insects, trees, planets and solar systems.

KATE RUSSELL is a technology journalist and BBC *Click* presenter

VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

4-14 JUNE

Glasgow Science Festival

Various venues, glasgowsciencefestival.org.uk

THIS FESTIVAL HAS something for everyone. You can even be a chemistry 'gin-ius' and distil your own G&T.

6 JUNE

Sculpting Anatomy: One-Day Modelling Class

Hunterian Museum, London, 10.30am-4.30pm, £35, rcseng.ac.uk/museums/hunterian

JOIN THIS WORKSHOP in which sculptor Eleanor Crook explains the anatomy of the head and neck with wax modelling.

11 JUNE

Digital Summit

Emmanuel Centre, London, 2pm-7pm, intelligencesquared.com

JOIN JAMAL EDWARDS (pictured) and other digital gurus as they discuss sci-fi scenarios soon to become everyday realities.

11 JUNE

Architecture And History Of London Zoo

Natural History Museum, Tring, Hertfordshire, 7pm-8pm, £4.50, nhm.ac.uk/tring

IN THIS FASCINATING talk, ZSL Fellow Paul Wilson reveals how the architecture of London Zoo has developed over the last two centuries to reflect the changes in our understanding of animals.

11 JUNE

The Story Of Life

Royal Institution, London, 7pm-8:30pm, £12, rigb.org

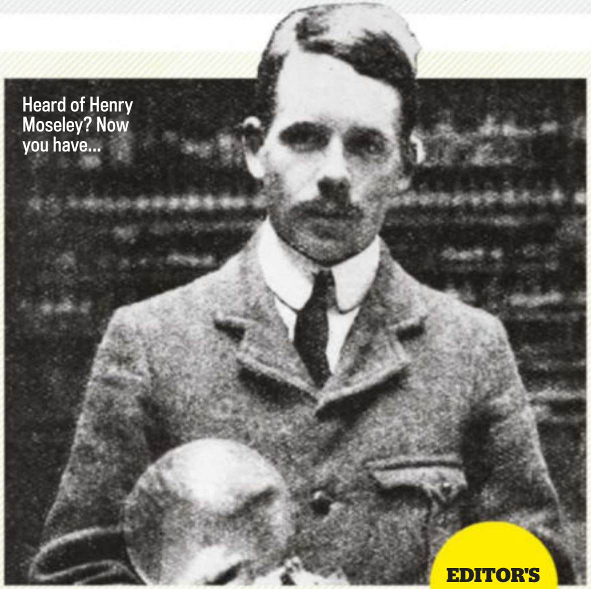
AT THIS TALK, find out how DNA confirmed the theory of evolution and why life evolved the way it did.

13 JUNE

Silver Screen Sci-Fi Showing

Royal Observatory Greenwich, London, 7pm-9pm, £8, rmg.co.uk

WATCH CULT CLASSIC *Silent Running* and then discuss the science behind it with one of the Royal Observatory astronomers.



Heard of Henry Moseley? Now you have...

EDITOR'S CHOICE

UNTIL **18** OCTOBER

'Dear Harry...' Henry Moseley: A Scientist Lost To War

Museum of the History of Science, Oxford, www.mhs.ox.ac.uk

HENRY MOSELEY. DOES his name ring a bell? Few will have heard of this English physicist, whose work on the X-ray spectra of the elements impacted the Periodic Table and contributed to the nuclear model of the atom. This great talent would surely have won a Nobel Prize in his lifetime if he hadn't died in WWI, aged just 27. This exhibition features his original apparatus and entries from his mother's diary, and reveals how his death changed the ways in which scientists were used during the war. Other related events are also taking place, including From Crystals To Atoms on 7 June and Beam Me Up, Harry! on 20 June.

19 JUNE - **22** NOVEMBER

Photography: A Victorian Sensation

National Museums Scotland, Edinburgh

AT THIS EXHIBITION, explore the Victorians' obsession with photography and discover more about its pioneers.

25-27 JUNE

Lancashire Science Festival

University of Central Lancashire, Preston, lancashiresciencefestival.co.uk

DISCOVER THE SCIENCE of *Star Wars* and the maths of Pixar, crack *Minecraft*'s code and get close to the world's 'ugliest' animals.

1 JULY

What A Wonderful World

Royal Institution, London, 7pm-8:30pm, £12, rigb.org

DID YOU KNOW that babies are powered by rocket fuel, slime moulds have 13 sexes and 98 per cent of the Universe is invisible? Join writer and *Focus* friend Marcus Chown (pictured) as he explains the world.

READ

THE LATEST SCIENCE BOOKS REVIEWED

H Hardback P Paperback

The Thrilling Adventures Of Lovelace And Babbage

Sydney Padua

Particular Books H £16.99

19TH CENTURY BRITAIN witnessed a golden era of mechanisation and invention. But what if the Victorians had gone further. What if they'd invented a steam-powered computer? What if these computers could be programmed and put to work in number-crunching factories along the banks of the Thames? Perhaps telegraph lines could have hung over rooftops and linked the machines, sending information back and forth, connecting the world in a Victorian internet. Imagine how different the world would have been if such a machine had been invented.

But it was. Thanks to the eccentric genius of Charles Babbage and his trusty mathematical sidekick Ada, Countess of Lovelace, we came within touching distance of steam-powered computers and the Victorian information age.

In actuality, the machine was never built, but from this imaginary universe comes an imaginary comic book, one that supposes – in exquisite detail – what the adventures of Lovelace and Babbage might have looked like.

> **"Equations and technical babble from real letters between Lovelace and Babbage set up punchlines"**

EDITOR'S CHOICE

THE THRILLING ADVENTURES OF
LOVELACE AND BABBAGE
*The (Mostly) True Story of the First Computer
DIFFERENCE ENGINE
SYDNEY PADUA

Sydney Padua's book is rich with in-jokes, warmth and charm. You are left in no doubt that this project was a labour of love for her – an ode to the marvellous, mysterious, non-existent Analytical Engine and its two imagineers. It's difficult not to be ignited by her enthusiasm.

While the adventures themselves are fictional, they all begin with a firm basis in truth, and Padua has a knack of spinning historical facts into playful storylines. Equations and technical babble from real letters between Lovelace and Babbage are used to set up punchlines. One comic has Babbage discover the unflattering comments made about him by Queen Victoria in her real-life diary. In another, Charles Dickens lines up to have his work spellchecked by the machine.

The foundations of truth make the jokes all the funnier, and Padua includes detailed but accessible footnotes to signpost the historical evidence for the reader. And all the way through the artwork is sylish and beautifully crafted.

There is so much to discover among Padua's 'concatenation of contraptions and labyrinthine of gears' that I'll treasure my copy for years to come.

■■■■■

HANNAH FRY is a lecturer in mathematics at University College London

MEET THE AUTHOR

Sydney Padua

Where did Lovelace and Babbage first meet?
Babbage used to throw big parties where he'd demonstrate a model he'd built of the Difference Engine – his first machine. Someone who was there said that everyone else looked at it like savages looking at a mirror, but Ada Lovelace could see the beauty in the invention and understood its workings.

What did they work on together?
Babbage abandoned the Difference Engine in favour of the more complicated Analytical Engine, which was meant to do any kind of calculation. It had storage and data transfer, and it could be programmed – just like a computer. Babbage was obsessed with its mechanics, whereas Lovelace was more interested in the software side. With Babbage, she wrote an algorithm for the machine, considered to be the first computer program.

Why didn't Babbage ever construct his Analytical Engine?
Babbage was almost incapable of delegating work to others. His machine was the size of a steam engine and made of tens of thousands of gears, but he was trying to do it on his own. Ultimately it was just really, really hard – it's not a disgrace not to successfully build a mechanical computer in the 1840s!

If you could travel back in time, what would you say to them?
I would say: "It's okay, you were right about everything!" Lovelace died young and Babbage died miserable, so it's quite a sad story. I think they would be very, pleased to hear that they were right and everybody else was wrong!

MORE ON THE PODCAST
Listen to the full interview with Sydney Padua at sciencefocus.com/podcasts

How To Clone A Mammoth

The Science Of De-Extinction

Beth Shapiro

Princeton H £16.95

BETH SHAPIRO'S NEW book *How To Clone A Mammoth* is about as close as you could get to sitting down with a nice cup of tea to have a decent chinwag with a mate about resurrecting the woolly mammoth. First of all: spoilers! The mammoth is gone. You can't clone it, and you'll never bring it back. Instead, Beth Shapiro and colleagues have set their sights on an all-new, genetically modified creation: an elephant that can survive in extreme cold. It'll be woolly, so it will sort of look like a mammoth and that's good enough for Shapiro. But she isn't interested in resurrecting species – she hopes that elephants grazing the Siberian tundra will help restore an ecosystem last seen over 10,000 years ago.

Refreshingly, she replaces hyperbole with humour to guide the reader through the basics of de-extinction science. Some of the hurdles are swept aside a little blithely, and I would have liked a more critical eye at times. But this is in part a manifesto for her research, and that personal touch brings warmth. Shapiro's belief that a woolly elephant is inevitable, and the right thing to do, is infectious. I'm not fully convinced, but I am excited.

■■■□□

DR TORI HERRIDGE is a palaeobiologist at the Natural History Museum

Testosterone

Sex, Power, And The Will To Win

Joe Herbert

Oxford University Press H £16.99

THERE ARE SO many properties of testosterone you could write a book about them. Well, that's exactly what Joe Herbert has done. Herbert has a knack for including interesting examples to illustrate his points, such as showing how testosterone affects the economy by citing the dominance of males working at stock exchanges.

The issue is that, by actively focusing on the properties of testosterone and how it affects our world, the text comes across as very reductionist. It portrays complex and subtle human behaviours like dating as down to the actions of a single molecule. In doing so, it presents a worryingly simplified view of humans and their development. It's hard to see how this could be avoided, but any psychologists will likely find it grating.

One point: Herbert's use of quotes is often excessive. It makes it seem like he's not confident enough in his own writing, so has to rely on more established names. Given the subject of this book, that's either amusingly ironic or a brilliant meta-joke. *Testosterone* is a very good read on an interesting subject, but it may anger scientists. Again, pretty ironic.

■■■□□

DR DEAN BURNETT is a lecturer of neuroscience at Cardiff University

Spirals In Time

The Secret Life And Curious Afterlife Of Seashells

Helen Scales

Bloomsbury Sigma H £16.99

MOLLUSCS. PRETTY DULL squidgy things, right? Nope. This fascinating group has been happily diversifying since the Cambrian period to occupy every environment except the sky. Nonetheless, an entire tome on the shelly ones is a pretty enormous feat. While *Spirals In Time* is certainly not a book to attempt in one sitting, it's enjoyable to dip in and out of as Helen Scales's zeal for her subject is completely infectious.

One fascinating section in *Spirals In Time* outlines the mechanisms that give molluscs the patterned shells that have been prized by humans for centuries. Scales explains that scientists are still uncertain of the exact pigments that give seashells their colouration, and aren't sure why the markings are even created in the first place. Could it be to stop the animals 'losing their place' as they grow their shell? Or can it all be explained through computer algorithms? Clearly, we don't fully understand molluscs, yet issues like overfishing and acidification of oceans mean they need our help. *Spirals In Time* will raise appreciation for these creatures, and maybe you'll even think twice before sprinkling the slug pellets.

■■■■□

ALICE LIPSCOMBE-SOUTHWELL is the production editor at *BBC Focus*

Cakes, Custard And Category Theory

Easy Recipes For Understanding Complex Maths

Eugenia Cheng

Profile Books P £12.99

MATHS IS EASY. So argues Eugenia Cheng in her new book *Cakes, Custard And Category Theory*. You do, however, need to appreciate her definition of easy. Cheng, who can be found on YouTube making mobius strips out of bagels, is a lecturer in pure mathematics at Sheffield University.

The first half of the book discusses many interesting aspects of mathematical theory. It explains, for example, why a bagel is like coffee cup (topologically). The second half focuses on category theory. Category theory is to maths what maths is to everything else; it aims to explain the rules of maths and tries to tie together seemingly disparate areas of theory.

Many consider maths a difficult and dry subject. But the baking-based analogies and fun tangents used to demonstrate the various ideas in the book are entertaining and diminish the mental gymnastics that abstract maths can require. While it would be hard to claim that this book makes maths easy, it leaves you with an appreciation for it… along with a craving for a piece of iterated Battenberg cake.

■■■■□

TOBIAS JOLLY is a statistician and a columnist at *Significance* magazine

THE GADGET SHOW 2015 ROUND-UP

Here's some of the great tech that adorned the show floor at the Birmingham NEC

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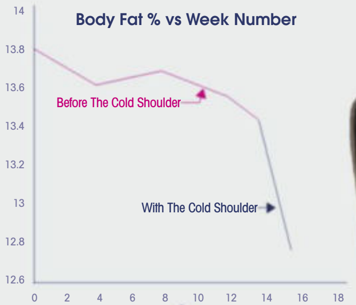

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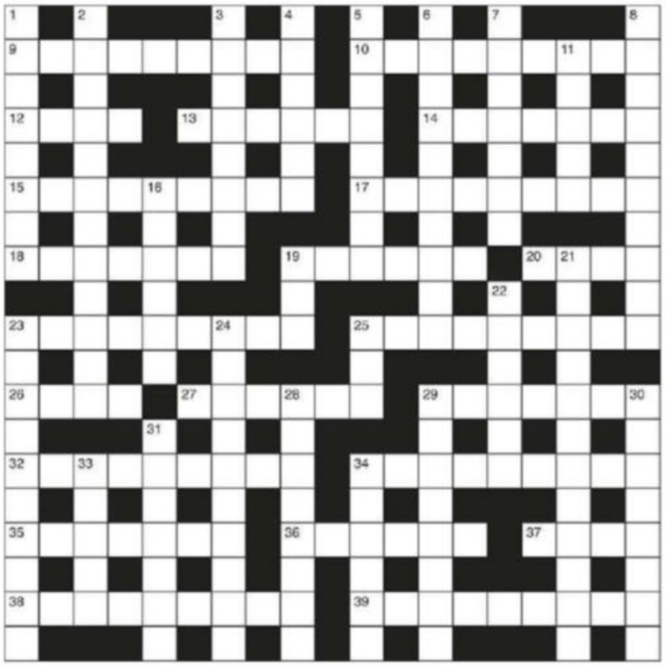
FOCUS CROSSWORD No 178

More online Solve puzzles from BBC's *Only Connect* hosted by Victoria Coren Mitchell at **http://bbc.in/1vCOzuY**



ACROSS

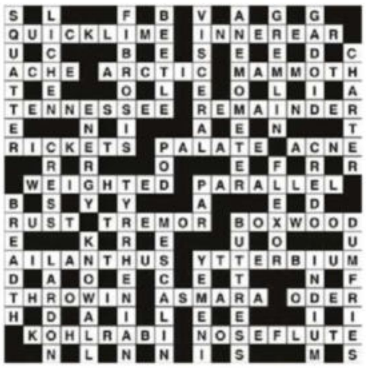
9 Rose, say, has encountered a gauge (9)
10 Like an impossible clue, unable to dissolve (9)
12 Basil telephones with deposit (4)
13 Effeminate, American place of learning (6)
14 Brush off award, getting in shape (7)
15 Butterfly to dump fruit for a start (6-3)
17 Manage to need my form, finding place to sign (9)
18 Deformity, thanks to treatment of piles (7)
19 Bird has ends of earthnut in throat (6)
20 Talk to a bird (4)
23 Eying this new dental assistant (9)
25 Porter gets hot running from something that flaps (9)
26 Parasites caught in fib (4)
27 Town to hold out until morning (6)
29 Endlessly respect a novice officer (7)
32 Rig Monaco's form of land management (9)
34 Deacon and God combine to get into shape (9)
35 Asian giant has to be included (7)
36 Belief that article is minute (6)
37 The burden we bear (4)
38 Best not to finish with hesitation by deadline (9)
39 Tail pouch designed for oil (9)

DOWN

1 Leaving to film a by-product (8)
2 Basis of computing fails igloo – no cable (7,5)
3 Book about tin sculpture from fabled place (8)
4 Happen to find harvest has increased (6)
5 Frenchman to insert composition left for singer (8)
6 A series on hospital department is harsh (10)
7 Send Molly an assumed name (7)
8 Bulletin points to landlord (10)
11 Hostility about British holy book (5)
16 Leave that woman with quiet rodent (6)
19 Tug back on the stomach (3)
21 Moved to greenhouse of foreign origin (12)
22 Class in charge of some acid (6)
23 Thus inhale preparation made from plant (10)
24 I will find minutia about religious sect (10)
25 Resistance unit starts to open his mind (3)
28 Both came round to make a sacrifice (8)
29 Dane lost location of volcanic rock (8)
30 Alight by mistake onto fallen material (8)
31 May get confused about defence group's structure (7)
33 Right to boot out an automaton (5)
34 Woman has peep around foreign port (6)

SOLUTION TO CROSSWORD No 175

Lesley Champion, JH Clay, Clive Roper, Kathy Humphrey and Margaret Baxter each solved issue 279's puzzle and receive a copy of *Through The Wormhole With Morgan Freeman* (Discovery, £39.99).



S	■	L	■	■	■	F	■	B	■	V	■	A	■	G	■	G	■	■
Q	U	I	C	K	L	I	M	E	■	I	N	N	E	R	E	A	R	■
U	■	C	■	■	■	B	■	E	■	S	■	E	■	E	■	D	■	C
A	C	H	E	■	A	R	C	T	I	C	■	M	A	M	M	O	T	H
T	■	E	■	■	■	O	■	L	■	E	■	O	■	L	■	I	■	A
T	E	N	N	E	S	S	E	E	■	R	E	M	A	I	N	D	E	R
E	■	■	■	N	■	I	■	■	■	A	■	E	■	N	■	■	■	T
R	I	C	K	E	T	S	■	P	A	L	A	T	E	■	A	C	N	E
■	■	R	■	R	■	■	■	O	■	■	■	E	■	F	■	R	■	R
■	W	E	I	G	H	T	E	D	■	P	A	R	A	L	L	E	L	■
B	■	S	■	Y	■	Y	■	■	■	A	■	■	■	E	■	D	■	■
R	U	S	T	■	T	R	E	M	O	R	■	B	O	X	W	O	O	D
E	■	■	■	K	■	R	■	E	■	■	■	U	■	O	■	■	■	U
A	I	L	A	N	T	H	U	S	■	Y	T	T	E	R	B	I	U	M
D	■	A	■	O	■	E	■	C	■	E	■	T	■	■	■	N	■	F
T	H	R	O	W	I	N	■	A	S	M	A	R	A	■	O	D	E	R
H	■	D	■	A	■	I	■	L	■	E	■	E	■	■	■	I	■	I
■	K	O	H	L	R	A	B	I	■	N	O	S	E	F	L	U	T	E
■	■	N	■	L	■	N	■	N	■	I	■	S	■	■	■	M	■	S

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IMAGINE IF CIVILISATION collapsed overnight and you woke to a world with no power, no internet and worst of all, no toast. How would you survive? Could civilisation rebuild itself after the apocalypse? In *Mad Max: Fury Road*, people survive by wearing gimp masks and driving around the desert in monster trucks, while Max does a lot of standing around looking macho.

Neither approach is a particularly good idea, says Leicester University's Lewis Dartnell, whose book *The Knowledge: How To Rebuild Our World From Scratch* could offer Max some handy hints. "There's a lot of dramatic tension to be had from a flawed, lone antihero going out to survive all on his own, but it's much better to combine your skill sets with those of other people," he says. There's safety and knowhow in numbers, so you'd be wise to befriend people with practical skills such as doctors and Bear Grylls. Oil and petrol will run out quickly after the apocalypse, so monster trucks should be used sparingly or pimped up to run on logs like they did in World War II. In a process called 'gasification', wood burned in a closed metal canister releases combustible gases like hydrogen and methane, which can be used as engine fuel.

> **"We'll have to rock the 'woolly leather look' while we reboot the chemical industry"**

Dartnell has also calculated that a single supermarket contains enough preserved goods to keep you alive for 54 years (63 if you eat pet food). A working knowledge of germ theory, coupled with the technical knowhow to purify water, will be essential. As the grace period offered by the leftovers of civilisation runs out, we'll have to start growing and preserving our own food. Fashion will suffer for a while. Synthetic fibres, invented in the last 50 years, involve complex organic chemistry, so we'll have to rock the 'woolly leather look' while we reboot the chemical industry. Potash, from wood ashes, can be used to make soap and paper. Lime, from seashells, can be used to produce disinfectant and mortar. But it's that most humble of materials, glass, that will see us through our darkest hour. Humans first made glass over 5,500 years ago, but it was the Romans who realised its potential to magnify things. From that it was a short hop to lenses, then the development of microscopes and telescopes. These tools have helped us to unravel everything from the mysteries of the cell to the miracles of the Cosmos. It's only with this level of insight that civilisation will be restored to its former glory. "Science made our modern world in the first place," says Dartnell. "So it's science that we need to rebuild it again." ■

HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

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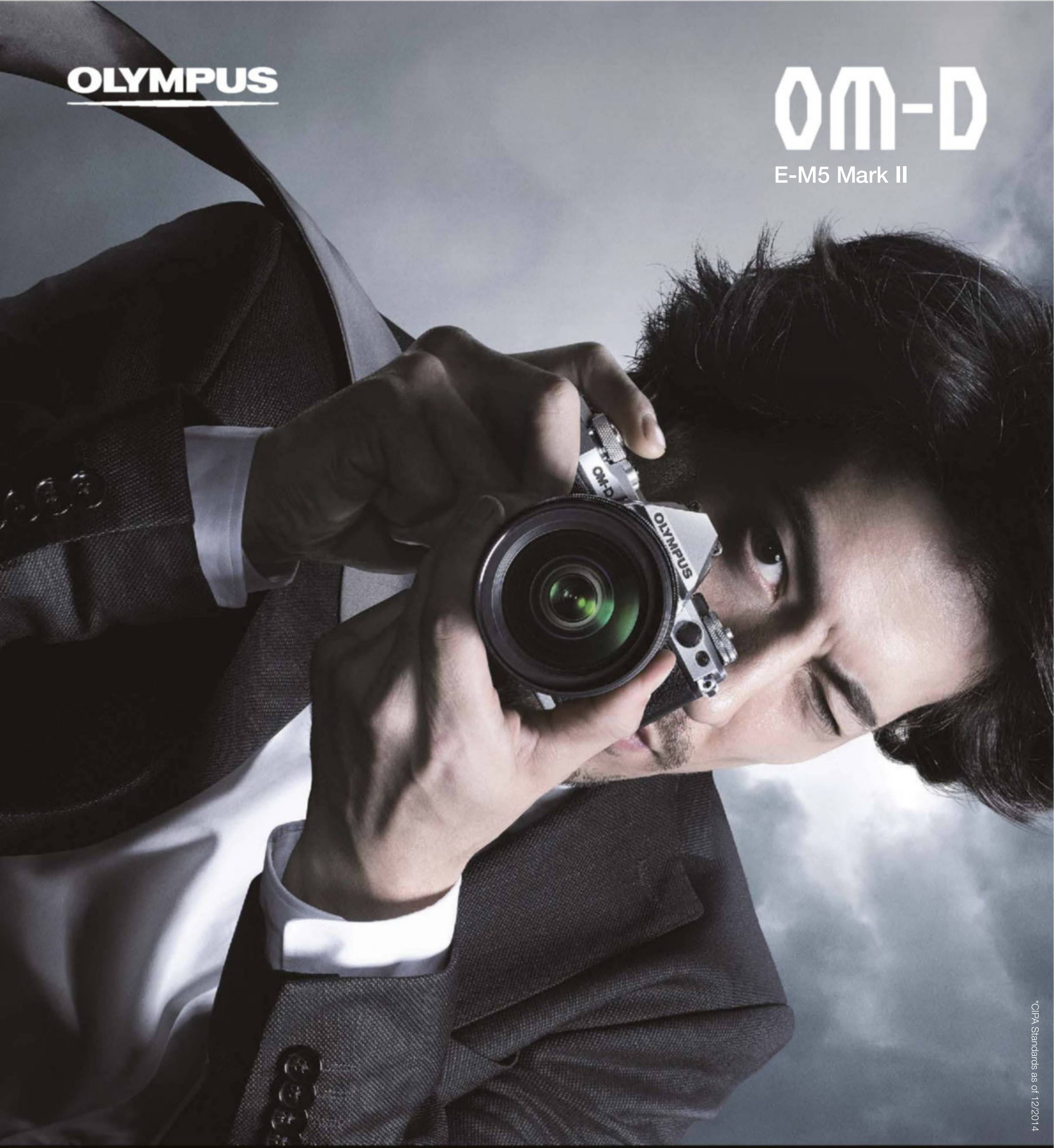

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